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**WITH THREE PLATES, TWO FOLDING CHARTS,
AND ONE CHART.**

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Page 277.—In the Table of Calculated Dimethylamino-Compounds (Acid) two items are transposed : " Benzaldimethylphenylenediamine A and B " *should come before* " Dimethylaminobenzalaniline A and B," leaving the figures in the columns exactly as they are. The error is, that the former substance has the figures ascribed to the latter. The mistake was discovered after the paper had gone to press.

ON A MINOR IMPROVEMENT IN THE MULTI-RANGE POTENTIOMETER.

By W. H. Logeman, M.A.

Among the many improvements which have been introduced into the construction of the direct-reading or "Crompton" potentiometer of late years, one of the most desirable is the provision of a separate branch contact for the standard-cell circuit, so as to avoid the necessity of moving the sliding contact each time it is required to test whether the main current is remaining constant. Another improvement which is frequently made in the more elaborate instruments of this type consists in the provision of one or two extra ranges, by shunting that portion of the main circuit which consists of the potential coils and slide-wire, and at the same time introducing into the circuit sufficient extra resistance to bring the total resistance up to its normal value.

It is when these two improvements are adopted in one instrument that the arrangements are not as convenient as might be desired. Thus, in one instrument of well-known make in my laboratory, there are three ranges available, the fall of the potential per section being adjusted to either $\frac{1}{10}$ or $\frac{1}{100}$ or $\frac{1}{1000}$ volt. If, however, we are using, for example, the last of these three ranges, and we wish to test the standard-cell balance, the following operations are necessary :—

1. The voltage switch is placed at "$\frac{1}{10}$ volt per section."
2. The circuit switch is placed at "Standard Cell."
3. The key marked "Standard Cell" is depressed.

The disadvantage of this arrangement does not merely lie in the loss of time involved in carrying out these three operations, though that in itself

is worth avoiding. The more important drawback lies in the fact that if, through an oversight, the user omits to perform either of operations (1) and (2), or if, having performed these correctly, he accidentally depresses the sliding-contact key instead of the standard-cell key, the result is a very violent deflection of the galvanometer, which, even if it is not damaged, may take a minute or two to settle down.

All these difficulties are entirely overcome in a simple instrument which I have constructed, and of which the connections are given in the accompanying diagram. It will be obvious that exactly the same method of construction can be used in the more elaborate instruments having a large number of potential coils.

In the diagram shown, there are two potential coils, each equal in resistance to 50 cm. of slide-wire, while the slide-wire, OO′, is 60 cm. long. The normal range of the instrument is thus from 0 to 1·6 volts by millivolts, and this range is in use when the range-plug is connecting B and D, as shown in the diagram. 'If we call R the resistance from A *via* O and O′ to B, then the coil between A and C is adjusted to $\dfrac{R}{9}$, while that between B and D is $\dfrac{9R}{10}$. It will thus be clear that if the plug is inserted between C and B, instead of between B and D, the total resistance of the main circuit will be the same as before, but the current through the potential-coils and slide-wire will have exactly $\frac{1}{10}$ of its previous value, and the range of the instrument will now be from 0–0·16 volt by tenths of a millivolt.

So far the arrangements represent the common practice in constructing

potentiometers, but if there were no further connections, it would be necessary for either E_1 or E_2 to be a standard cell, and to adjust the battery current with the standard cell in circuit in the usual way. It will be clear, however, that whichever range we are using, the P.D. between A and D will have always the same value if the main battery current is of the correct strength. The object of the standard cell is merely then to enable us to adjust the P.D. between A and D to the correct value, which I will call V. The arrangements for doing this are clearly shown in the diagram. A separate branch circuit, P Q, of comparatively high resistance, is connected from A to D and so adjusted that $\dfrac{P}{P+Q} = \dfrac{Es}{V}$, where Es is the E.M.F. of the standard cell. The standard cell is then connected across the terminals of P, through the galvanometer, by means of the double-pole two-way standard-cell key S.C.K., and the battery current adjusted by means of the rheostat, Rh., until a balance is obtained. With this arrangement it will be seen that it is immaterial in what position any switch on the instrument is placed, the standard-cell balance is always tested by merely depressing the standard-cell key.

I may say that experience has shown that the convenience of this instrument is quite as great as I expected it would be. Sudden violent deflections of the galvanometer never occur, and the simplicity of the operation of testing the standard-cell balance is in striking contrast with the troublesome series of operations required with the more elaborate instrument referred to above.

It seems to me that it might be worth while for some firm of instrument makers to place on the market a simple form of potentiometer, such as I have described, as well as to adopt the same principle in their more expensive instruments. A potentiometer reading by millivolts up to 1·5 volts is accurate enough for almost all such work as the calibration of high-class ammeters and voltmeters. My own home-made instrument is accurate to about 1 part in 1000, which is quite sufficient for many experiments in which the precision of a good deflection instrument is not enough.

THE CONTROL OF EVAPORATION BY THE TEMPERATURE OF THE AIR.

By J. R. SUTTON.

The observations discussed in this paper deal with the evaporation from the surface of the water contained in a metal tub sheltered by a louvred screen. The tub is of copper, shaped slightly tapering something like a flower-pot, its dimensions being—height 22 inches, diameters at top and bottom 15 and 13 inches. The tapering form was adopted in order that frost should not burst the tub. The screen is 46 inches long by 33 inches broad by 72 inches high over all.

A small float in the surface of the water actuates a light lever arm mounted on needle points, the variations in the height of the water being magnified ten times. The small spherical bulb of a B.T. thermometer dips just beneath the water surface.

On the whole the apparatus works fairly well. That the bulb of the thermometer is not at the same depth beneath the surface at the end of a dry day as it was' at the beginning is to be noted, but this circumstance does not seem to affect the temperature readings very much. Of somewhat more importance is the disturbance of the temperature gradient in the tub when fresh water is added each evening, which, however, is minimised as much as possible by adding water of like temperature.

Table I gives mean annual values of evaporation and of water temperature deduced from observations made during the fourteen years 1906 to 1919.

TABLE I.—*Evaporation in the Shade of a Louvred Screen.*

Water Temperatures.			Evaporation.		
Hour.	F.	C.	Hour.	inch.	mm.
VIII . .	57·0°	13·9°	XXIII–VIII	19·03	483
XI . .	60·6	15·9	VIII–XI .	12·24	311
XIV . .	64·7	18·2	XI–XIV .	15·14	385
XVII . .	65·5	18·6	XIV–XVII .	12·97	329
XX . .	63·7	17·6	XVII–XX .	8·54	217
XXIII .	61·9	16·6	XX–XXIII .	7·34	186
			Total .	75·27	1911

For our present purpose the only point in this table to be noticed specially is the lack of agreement between the curves of temperature and of evaporation : the water level sinking much more rapidly in the morning with the lower water temperatures than it does in the evening with the higher ones. In fact the rates of evaporation agree better with the air temperatures than they do with those of the water. The mean differences between air and water are :—

Time.			Air.	Water.	Difference.
			$^{\circ}$	$^{\circ}$	
VIII–XI	.	.	66·1	58·8	+ 7·3
XI–XIV	.	.	74·4	62·6	+11·8
XIV–XVII	.	.	74·9	65·1	+ 9·8
XVII–XX	.	.	67·9	64·6	+ 3·3
XX–XXIII	.	.	60·4	62·8	− 2·4

Thus we see that the rate of evaporation is at its highest when the difference between the temperatures $(A-W)$ of air and water is a maximum. This result, so far as it goes, agrees with previous results showing the importance of the relative humidity in inducing evaporation. That is, other things being equal, water evaporates more rapidly into a dry air than it does into a damp one, for any given dewpoint. Our main object is to carry the investigation of this point a step further.

The simplest and most commonly used evaporation formula is

$$E = n(V-v),$$

where E is the quantity of water evaporated, V and v the vapour pressures at the temperatures of the water and of the dewpoint respectively, and n a constant.

Stefan's formula for the evaporation from a circular basin of radius a is

$$E = 4ka(P-v)/(P-V),$$

where k is the coefficient of diffusion, and P the barometric pressure.

Strictly speaking, simple formulæ of this kind only apply to laboratory experimental conditions, although they may do well enough to express in a rough way the natural evaporation over periods of time running to months or years. For short intervals such as hours or small fractions of a day under rapidly changing meteorological conditions they are quite inadequate, as we shall see.

With the object of establishing a basis of discussion, observations of evaporation from the metal tub extending over the two years 1918 and 1919

have been studied in detail,—first, for the three-hour period VIII–IX (when the air temperature is rising, and averages higher than that of the water), and, second, for the three-hour period XX–XXIII (when the air temperature is falling, and averages lower than that of the water). Summaries of the results are given in Tables II and III. The mean dew-points and humidities have been computed from the ordinary psychrometric formula after the wet-bulb readings had been corrected for wind movement.*
The tabulated speeds of the wind are those for a height of 45 feet, which average about four times as great as those near the ground. The influence of the wind is not great on the whole and will not be considered here.

The observations have been arrayed into grades of water temperature of 5° F. each, each grade being subdivided according to relative humidities below and above the median.

TABLE II.—*Summary of Observations*, VIII *to* XI.

No. of Times.	Evapora- tion. Inch.	Water Temp.	Air Temp.	Dew- point.	Relative Humidity. Per cent.	Wind M/H.	*n.*
			Water at 45° to 49°·9 F.				
45	·02222	47·9	55·6	31·3	40	5·0	·141
46	·01913	47·3	51·6	37·9	60	5·9	·193
			Water at 50° to 54°·9.				
60	·02667	52·7	61·6	32·7	35	6·0	·125
60	·01933	52·2	56·8	42·1	59	7·3	·157
			Water at 55° to 59°·9.				
46	·03261	57·9	67·7	36·3	32	6·3	·123
44	·02250	57·1	62·9	47·5	59	7·6	·163
			Water at 60° to 64°·9.				
61	·03705	62·7	72·5	41·1	34	6·9	·119
59	·02186	62·9	67·6	54·7	64	7·3	·150

* *Cf.* J. R. Sutton, "Comparison between Glaisher's Factors and Ferrel's Psychrometric Formula," Q.J.R. Met. S., 1906.

TABLE III.—*Summary of Observations*, XX *to* XXIII.

No.	Evapora- tion. Inch.	Water Temp.	Air Temp.	Dew- point.	Relative Humidity. Per cent.	Wind M/H.	n.

Water at 50° *to* 54°·9 *F.*

| 55 | ·01365 | 52·6 | 49·8 | 31·3 | 45 | 4·4 | ·062 |
| 54 | ·01167 | 52·8 | 48·9 | 38·4 | 68 | 4·4 | ·064 |

Water at 55° *to* 59°·9.

| 48 | ·02021 | 57·1 | 54·1 | 29·7 | 40 | 5·3 | ·067 |
| 55 | ·01527 | 57·1 | 53·6 | 38·1 | 61 | 4·0 | ·065 |

Water at 60° *to* 64°·9.

| 43 | ·02907 | 62·6 | 60·6 | 32·9 | 36 | 5·4 | ·076 |
| 41 | ·01341 | 62·8 | 60·0 | 49·4 | 70 | 4·8 | ·061 |

Water at 65° *to* 69°·9.

| 73 | ·03356 | 67·5 | 65·7 | 38·8 | 39 | 5·3 | ·077 |
| 68 | ·01397 | 67·5 | 64·9 | 57·3 | 77 | 4·8 | ·069 |

In Tables II and III—

Col.1 gives the number of observations in each subdivision of a grade ;

Col. 2 the mean evaporation in three hours ;

Col. 3 the mean temperature of the water ;

Col. 4   ,,   ,,   ,,   air ;

Col. 5   ,,   ,,   ,,   dewpoint ;

Col. 6   ,,   relative humidity ;

Col. 7 the hourly mean speed of the wind ; and

Col. 8 the values of n calculated from the first formula above.

The mean value of n in Table II is ·146, whereas in Table III it is only ·068. In other words, for given values of $V-v$, the evaporation is greater or less according as the temperature of the air is higher or lower respectively than that of the water. Compare, for instance, the following pairs of lines :—

	Evapora-tion. Inch.	Water Temp.	Air Temp.	Dew-point.	Relative Humidity. Per cent.	Wind M/H.	n.
Table II	·02222	47·9	55·6	31·3	40	5·0	·141
Table III	·02021	57·1	54·1	29·7	40	5·3	·067
Table II	·02667	52·7	61·6	32·7	35	6·0	·125
Table III	·02907	62·6	60·6	32·9	36	5·4	·076

Here we have the remarkable result that, although the water tempera-tures differ by nine or ten degrees, all the other concurrences in each pair are pretty much alike. At first sight one would expect just the opposite, reasoning from the formula ; also that the warmer moist air above the water surface would be readily displaced by the colder and denser outside air, and so carry off the water vapour more quickly. But it appears from the tables that there is a stronger tendency than that for the colder moist air above the water to be displaced by the warmer and drier free air from outside. Yet this, at the best, can only be a partial explanation, as may be proved by comparing the evaporation from our gauge with that from a large tank sunk below the level of the ground under the open sky, and with that from a Piche Atmometer suspended in the free air in the shade. Expressed in ratios per thousand these are—

			Screened Tub.	Open-air Tank.	Screened Piche Atmometer.
XXIII–VIII	.	.	253	253	210
VIII–XI	.	.	163	134	157
XI–XIV	.	.	201	200	215
XIV–XVII	.	.	172	212	204
XVII–XX	.	.	114	106	121
XX–XXIII	.	.	97	95	93

This shows that at night, when the water is warmer than the air, the tub and the tank are evaporating at the same relative rate, which is faster than that of the Piche Atmometer. But during the warmest hours of the day the tank is evaporating relatively faster than the tub in spite of the fact that the assumed cool, moist air immediately above it could only escape by rising, which is not likely to be a rapid process. In passing it may be noted that the Piche Atmometer indicates roughly the evaporation losses from the jacket of a wet-bulb thermometer. Its daily maximum comes later than that of the tub, but earlier than that of the tank.

Again consider the following pair of lines :—

	Evapora-tion. Inch.	Water Temp.	Air Temp.	Dew-point.	Relative Humidity. Per cent.	Wind M/H.	n.
Table II	·03705	62·7	72·5	41·1	34	6·9	·119
Table III	·02907	62·6	60·6	32·9	36	5·4	·076

Here we see that, according to the formula, the second line should show the greater rate of evaporation because, while the water temperatures are practically the same, the dewpoint is much lower.　But it shows much less as (or, shall we say, because) the air temperature is less.

If we pick out all the **XX–XXIII** simultaneous observations in which air and water have their temperatures nearly the same, not differing by more than one degree F. (so as to get something like laboratory conditions), we have the mean results of Col. A, Table IV.

Again, if we pick out all the **XX–XXIII** simultaneous observations in which the air temperature exceeds that of the water (so as to get conditions approximating in type to those of Table II) we have the mean results of Col. B.

An essential factor in the problem is, of course, the temperature of the indefinitely thin immediate water surface.　If a pan of water, starting at the temperature of the air, be allowed to evaporate freely, the lowest temperature it can attain by evaporation alone will be that of the wet bulb ; though probably it never falls quite so low as that.　Now if we pick out all the observations in which the temperature of the water shown by the thermometer in use is within a degree of the simultaneous wet-bulb reading * we have the mean result of Col. C.

Col. D gives the mean of all the **XX–XXIII** observations (Table III) ; and Col. E the mean of all those of VIII–XI (Table II).

TABLE IV.—*Selected Observations.*

	A.	B.	C.	D.	E.
Water Temperature . .	60·8	60·5	52·4	60·0	55·1
Air ,, . .	60·7	63·0	57·7	57·2	62·0
Dewpoint ,, .	38·0	36·7	47·8	39·5	40·4
Relative Humidity . .	46	39	71	54	48

* Other conditions besides evaporation, however, will have combined to make it so.

TABLE IV.—*Selected Observations* (contd.).

	A.	B.	C.	D.	E.
	°	°	°	°	°
Wind M/H . . .	5·7	7·2	6·4	4·8	6·5
Evaporation, 3 h. . .	·02583	·03387	·01565	·01885	·02517
n	·085	·109	·257	·068	·146
Number . . .	48	31	23	437	421
A—W . . .	−0·1	+2·5	+5·3	−2·8	+6·9
Wet-bulb Temp.	. .		. .	52·0	

The value of n in Col. C is surprisingly great. The other columns conform to what has been said above, *i.e.* that the rate of evaporation, expressed by n, increases as the air temperature rises above that of the water.

With the object of getting an idea of what goes on in the space immediately above the tub, a Piche Atmometer was suspended so that its paper disc was at a height of about ·75 inch above the water. A thermometer was also placed with its bulb at the same level. Atmometer and thermometer were as near as could be to the centre of the space. Seven months of observation of these are epitomised in Table V. In this table, Cols. 1 and 3 show times; Col. 2 shows the ratios per thousand which the mean evaporation from the Piche Atmometer above the water bears to that from a similar instrument in the shade of the free air in another screen. Cols. 4 and 5 are synchronous temperatures.

TABLE V.—*Evaporation and Temperature Comparisons.*

Period.	Piche Atmometer.	Time.	Temperatures.	
			Above Water.	Free Air.
XXIII–VIII . .	648	VIII	59·0	59·2
VIII–XI . . .	775	XI	70·5	71·1
XI–XIV . . .	789	XIV	75·7	75·6
XIV–XVII . .	806	XVII	70·3	71·6
XVII–XX . . .	731	XX	60·6	60·8
XX–XXIII . .	644	XXIII	56·3	55·9
		Max.	76·5	77·2
Total . . .	740			

The unexpected result elicited by Table V is that while the evaporation by the Atmometer is reduced by 26 per cent. by the contiguity of the water, the temperature at the same place is affected very little. Some rough observations with a minimum thermometer proved that the space above the water was a little warmer after midnight than the free air, indicating probably a small convective upcast of damp air. During the day the water vapour seems to have been removed more by the slow process of diffusion, assisted it may be by the stronger wind.

It is commonly understood that a water surface is cooled by evaporation. And a hasty conclusion would be that a thermometer dipping just beneath the surface must show a higher temperature than the immediate surface itself. But such a conclusion is rendered doubtful by the experiments and observations described here. It seems rather that the actual water surface is warmed as much by contact with the air as it is cooled by evaporation ; and also that when the water is the warmer, some of its heat energy is expended in raising the temperature of the superincumbent air. If this be really the case, an evaporation formula should be based upon the temperature of the air, and not upon that of the water as determined by a thermometer dipping into it. Not that any formula can rightly be called a law. The only law of evaporation is expressed very simply by the relation

$$E = f(T),$$

(where T is the temperature of the indefinitely thin top layer of water), giving the optimum rate. Air pressure and temperature, vapour pressure, wind, diffusion, and convection, are of the nature of perturbations, some accelerating and some retarding the rate of evaporation as they find it, modified by the rest. The best formula can only express the conditions, meteorological or otherwise, modifying the simple law.

Bearing the limitations of any formula in mind, it may still be proved that the temperature of the air is of fundamental importance in the meteorological process of evaporation. For if we write the first formula

$$E = n(p - v),$$

where p is the vapour pressure at the temperature of the air, and calculate n afresh from the normals of Tables II and III, its sixteen values become :—

Mean Water Temperature.	n. By Table II.	n. By Table III.
45° to 49°·9 . .	·083 ·120	
50° to 54°·9 . .	·074 ·100	·075 ·102
55° to 59°·9 . .	·070 ·091	·080 ·084
60° to 64°·9 . .	·069 ·089	·085 ·081
65° to 69°·9 . .	..	·085 ·096
Means . . .	·087	·086

There is a good deal of variation in the individual values, due, in all probability, to the rapidly changing conditions in the three-hour intervals, operative more especially on the values of *n* derived from Table II. But these values are more consistent, and the two tables are brought into closer agreement. Moreover, the mean value of *n* found in this new way agrees with that of Col. A, Table IV, where air and water are at the same temperature. Hence, as a first approximation, *p* is a better element to use than V is. This is a further illustration of the general law that water vapour diffuses along the relative humidity gradient.

NOTE ON THE COEVANESCENCE OF THE PRIMARY MINORS OF AN AXISYMMETRIC DETERMINANT.

By Sir Thomas Muir, F.R.S.

1. In any n-line axisymmetric determinant each coaxial primary minor is necessarily independent of n of the elements; and, one such being selected, the others are expressible in terms of the said n elements with groups of secondary minors for their cofactors. Thus, in the case of the determinant

$$\begin{vmatrix} a & h & g & p \\ h & b & f & q \\ g & f & c & r \\ p & q & r & d \end{vmatrix} \text{ or } \Delta, \text{ say,}$$

where the coaxial primary minors A, B, C, D are

$$\begin{vmatrix} b & f & q \\ f & c & r \\ q & r & d \end{vmatrix}, \quad \begin{vmatrix} a & g & p \\ g & c & r \\ p & r & d \end{vmatrix}, \quad \begin{vmatrix} a & h & p \\ h & b & q \\ p & q & d \end{vmatrix}, \quad \begin{vmatrix} a & h & g \\ h & b & f \\ g & f & c \end{vmatrix}$$

the first is independent of the first-row elements a, h, g, p: and, the others being expanded in terms of a, h, g, p and their complementaries in the second and third rows, the sum of the expansions can be put in the form

$$a\Theta_a + h\Theta_h + g\Theta_g + p\Theta_p,$$

where

$$\Theta_a = (cd - r^2) + (bd - q^2) + (bc - f^2),$$
$$\Theta_h = (pq - dh) + (fg - ch),$$
$$\Theta_g = (pr - dg) + (fh - bg),$$
$$\Theta_p = (qr - cp) + (hq - bp).$$

On this simple observation the results of our note are founded.

2. By substituting for a, h, g, p in the first rows of B, C, D the elements

$$h, b, f, q$$

of the second row of Δ, we see that B is changed into $-$H, and C and D into 0 : also, that by substituting in the same way the elements

$$g, f, c, r,$$

C is changed into $-$G, and B and D into 0 : and, lastly, that the substitution of

$$p, q, r, d$$

changes D into $-$P, and B and C into 0. We thus have

$$\left.\begin{array}{l} a\Theta_a + h\Theta_h + g\Theta_g + p\Theta_p = \mathrm{S} - \mathrm{A} \\ h\Theta_a + b\Theta_h + f\Theta_g + q\Theta_p = \quad -\mathrm{H} \\ g\Theta_a + f\Theta_h + c\Theta_g + r\Theta_p = \quad -\mathrm{G} \\ p\Theta_a + q\Theta_h + r\Theta_g + d\Theta_p = \quad -\mathrm{P} \end{array}\right\}$$

where we use S to stand for $\mathrm{A} + \mathrm{B} + \mathrm{C} + \mathrm{D}$.   Solving then for the Θ's, we obtain

$$\Theta_a = \begin{vmatrix} \mathrm{S-A} & h & g & p \\ -\mathrm{H} & b & f & q \\ -\mathrm{G} & f & c & r \\ -\mathrm{P} & q & r & d \end{vmatrix} \div \Delta$$

whence

$$\begin{aligned} -\Theta_a . \Delta &= (\mathrm{A} - \mathrm{S})\mathrm{A} + \mathrm{H}^2 + \mathrm{G}^2 + \mathrm{P}^2 \\ &= (\mathrm{A} - \mathrm{S}, \mathrm{H}, \mathrm{G}, \mathrm{P} \emptyset \mathrm{A}, \mathrm{H}, \mathrm{G}, \mathrm{P}) ; \end{aligned}$$

and similarly

$$\begin{aligned} -\Theta_h . \Delta &= (\mathrm{A} - \mathrm{S}, \mathrm{H}, \mathrm{G}, \mathrm{P} \emptyset \mathrm{H}, \mathrm{B}, \mathrm{F}, \mathrm{Q}) , \\ -\Theta_g . \Delta &= (\quad \ldots \quad \emptyset \mathrm{G}, \mathrm{F}, \mathrm{C}, \mathrm{R}) , \\ -\Theta_p . \Delta &= (\quad \ldots \quad \emptyset \mathrm{P}, \mathrm{Q}, \mathrm{R}, \mathrm{D}) . \end{aligned}$$

Had we begun with S$-$B instead of S$-$A we should in similar manner have reached

$$\begin{aligned} -\Theta_b . \Delta &= (\mathrm{H}, \mathrm{B} - \mathrm{S}, \mathrm{F}, \mathrm{Q} \emptyset \mathrm{H}, \mathrm{B}, \mathrm{F}, \mathrm{Q}) , \\ -\Theta_f . \Delta &= (\quad \ldots \quad \emptyset \mathrm{G}, \mathrm{F}, \mathrm{C}, \mathrm{R}) , \\ -\Theta_q . \Delta &= (\quad \ldots \quad \emptyset \mathrm{P}, \mathrm{Q}, \mathrm{R}, \mathrm{D}) , \end{aligned}$$

and, on advancing still further,

$$\begin{aligned} -\Theta_c . \Delta &= (\mathrm{G}, \mathrm{F}, \mathrm{C} - \mathrm{S}, \mathrm{R} \emptyset \mathrm{G}, \mathrm{F}, \mathrm{C}, \mathrm{R}) , \\ -\Theta_r . \Delta &= \quad \ldots \quad \emptyset \mathrm{P}, \mathrm{Q}, \mathrm{R}, \mathrm{D}) . \end{aligned}$$

$$-\Theta_d . \Delta = (\mathrm{P}, \mathrm{Q}, \mathrm{R}, \mathrm{D} - \mathrm{S} \emptyset \mathrm{P}, \mathrm{Q}, \mathrm{R}, \mathrm{D}) .$$

3. Utilising in a body the equalities thus obtained, we have

$$
\begin{vmatrix} A-S & H & G & P \\ H & B-S & F & Q \\ G & F & C-S & R \\ P & Q & R & D-S \end{vmatrix} \cdot \begin{vmatrix} A & H & G & P \\ H & B & F & Q \\ G & F & C & R \\ P & Q & R & D \end{vmatrix} = (-\Delta)^4 \begin{vmatrix} \Theta_a & \Theta_h & \Theta_g & \Theta_p \\ \Theta_h & \Theta_b & \Theta_f & \Theta_q \\ \Theta_g & \Theta_f & \Theta_c & \Theta_r \\ \Theta_p & \Theta_q & \Theta_r & \Theta_d \end{vmatrix} ;
$$

and, as the second determinant here is known to be equal to Δ^3, and the first can be readily shown to be equal to

$$
\Delta(S_3{}^2 S_2 - S_3 S_1 \Delta + \Delta^2),
$$

where S_m stands for the sum of the m-line coaxial minors of Δ, there is at once deduced

$$
\begin{vmatrix} \Theta_a & \Theta_h & \Theta_g & \Theta_p \\ \Theta_h & \Theta_b & \Theta_f & \Theta_q \\ \Theta_g & \Theta_f & \Theta_c & \Theta_r \\ \Theta_p & \Theta_q & \Theta_r & \Theta_d \end{vmatrix} = S_3{}^2 S_2 - S_3 S_1 \Delta + \Delta^2,
$$

the Θ's being, as above defined, readily specifiable aggregates of secondary minors of Δ.

The same result is reached by multiplying the determinant of the Θ's by Δ.

4. The procedure followed throughout the foregoing is equally effective when the order of the originating determinant is higher than the 4th. When the order is the 3rd, the determinant being

$$
\begin{vmatrix} a & h & g \\ h & b & f \\ g & f & c \end{vmatrix},
$$

the final outcome is the curious equality

$$
\begin{vmatrix} A-S & H & G \\ H & B-S & F \\ G & F & C-S \end{vmatrix} = \Delta \begin{vmatrix} a-s & h & g \\ h & b-s & f \\ g & f & c-s \end{vmatrix}.
$$

5. Returning to § 2, and grouping a select four of the equalities, namely,

$$
\begin{aligned}
-\Theta_a \cdot \Delta &= (A-S)A + & H^2 & + & G^2 & + & P^2 \\
-\Theta_b \cdot \Delta &= H^2 & +(B-S)B+ & F^2 & + & Q^2 \\
-\Theta_c \cdot \Delta &= G^2 & + & F^2 & +(C-S)S+ & R^2 \\
-\Theta_d \cdot \Delta &= P^2 & + & Q^2 & + & R^2 & +(D-S)D
\end{aligned}
$$

2

we see that if $S=0$ the right-hand members become pure sums of squares, and that if further $\Delta=0$ each of these squares must vanish. We thus reach the important theorem originally established by C. K. Russian in 1902 that *If an axisymmetric determinant vanish and also the sum of its primary coaxial minors, then every primary minor must vanish.** A glance at the close of § 3 shows that under the same conditions the determinant of the Θ's also vanishes.

6. The similar theorems prior to Russian's agreed in requiring the condition $\Delta = 0$, but differed as to the additional requirements regarding the coaxial primary minors, one insisting on the vanishing of all of them and another on the vanishing of $n-1$ of them. The total withdrawal of the condition $\Delta = 0$ and the confinement of the data to the vanishing of co axial primary minors does not seem to have been seriously attempted. In this last connection I have elsewhere † suggested the use of the vanishing aggregates got by multiplying any row of Δ by any other row of its adjugate.

RONDEBOSCH, S.A.,
24th August 1922.

* Russian, C. K. "On a New Property of Symmetric Determinants" (in Russian). Mem. . . . Soc. . . . New Russia (Odessa), xxvi, pp. x–xv. The same theorem, he shows, holds for zero-axial skew determinants.

The writer's name appears in Western catalogues as *Roussiane* or *Rusjan.*

† Math. Quest. and Sol., iv, pp. 82–83.

ON . THE MATHEMATICS OF THE HOMOGENEOUS BALANCED ACTION.

By John P. Dalton.

(University of the Witwatersrand, Johannesburg.)

§ 1. Introduction.

In a paper published last year * it was shown how the integrated velocity equations of chemical reactions could be written down in terms of a certain function, viz. :—

$$\psi(n) = \frac{1}{n-1} \log_e \frac{1 - \frac{\lambda}{n}}{1 - \lambda} \quad . \qquad . \qquad . \qquad . \qquad (1)$$

The integrated equation of the ordinary bi-molecular reaction $A + B = C + D$ then becomes

$$\psi(n) = ka\vartheta \quad . \qquad . \qquad . \qquad . \qquad . \qquad (2)$$

where a is the initial concentration of A, na that of B, λa is the amount of A transformed in time ϑ, and k is the velocity constant. The purpose of the present note is to show how the same function may be employed in the treatment of the homogeneous balanced action.

§ 2. The Balance Point.

Let a, b, c, d be the initial concentrations of the four reactants in the balanced action

$$A + B \rightleftharpoons C + D$$

and let k and k' be the velocity constants of the forward and reverse reactions respectively. Then the differential equation to the reaction is the well-known

$$\frac{dx}{dt} = k(a-x)(b-x) - k'(c+x)(d+x) \quad . \qquad . \qquad (3)$$

* J. P. Dalton, Trans. R.S.S.A., ix, p. 223 (1921).

where x is the net forward transfer in time t. For a state of balance $dx/dt = 0$, and hence ξ the total transfer forward when the state of balance has been reached is given by

$$\xi^2(k-k') - \xi[k(a+b) + k'(c+d)] + kab - k'cd = 0 \quad . \quad . \quad (4)$$

The discriminant of this quadratic may be written in the form

$$\Delta = [k(a-b) + k'(c-d)]^2 + 4kk'(a+c)(b+d) \quad . \quad . \quad (5)$$

Δ is essentially positive, so that the roots of the quadratic in ξ are both real; hence two balance points are always theoretically possible, their values being

$$\xi', \xi = \frac{k(a+b) + k'(c+d) \pm \sqrt{\Delta}}{2(k-k')} \quad . \quad . \quad . \quad (6)$$

The initial velocity of the reaction is

$$\left(\frac{dx}{dt}\right)_{x=0} = kab - k'cd \quad . \quad . \quad . \quad . \quad (7)$$

If $kab > k'cd$ the reaction proceeds in the forward direction and ξ must be positive, while if $kab < k'cd$ it proceeds in the reverse direction and ξ must be negative.

In the former case, $(kab > k'cd)$, if $k > k'$ then both roots of (4) are positive and the balance point is given by the smaller of the two roots, *i.e.* by the negative sign in (6). If $k < k'$ the roots are of opposite sign, the negative root being the larger numerically, and since the reaction is forward, the balance point must be the positive root; hence the negative sign in (6) must again be taken.

In the latter case, $(kab < k'cd)$, if $k > k'$ the roots are of opposite sign, the positive root being the larger numerically; since the reaction is in the reverse direction the balance point must be the negative root, and once more the negative sign in (6) must be taken. And if $k < k'$ both roots are negative, and the reaction terminates when the numerically smaller value is reached. In every case, therefore, the negative sign in (6) must be taken, and the chemical balance point is always

$$\xi = \frac{k(a+b) + k'(c+d) - \sqrt{\Delta}}{2(k-k')} \quad . \quad . \quad (8)$$

or, in terms of the equilibrium constant, $K = \dfrac{k}{k'}$,

$$\xi = \frac{K(a+b) + (c+d) - \sqrt{\Delta'}}{2(K-1)} \quad . \quad . \quad (8')$$

where

$$\Delta' = [K(a-b)+(c-d)]^2 + 4K(a+c)(b+d) \qquad . \qquad . \quad (5')$$

§ 3. The Second Root, ξ'.

Although ξ' is thus ruled out as a possible balance point, it may still be usefully employed in the mathematical formulation of the result. Equation (3) may now be written in the form

$$\frac{dx}{(x-\xi)(x-\xi')} = (k-k')dt \quad . \qquad . \qquad . \qquad . \quad (9)$$

And if we write $x=\lambda\xi$, $\xi'=n\xi$, $t=\vartheta$, the integral becomes

$$\frac{1}{n-1}\log\frac{1-\dfrac{\lambda}{n}}{1-\lambda} = (k-k')\xi\vartheta \quad . \qquad . \qquad . \qquad . \quad (10)$$

or

$$\psi(n) = (k-k')\xi\vartheta \qquad . \qquad . \qquad . \qquad . \quad (11)$$

This is exactly the same form as (2), the equation to the complete reaction. The end-point ξ takes the place of the lowest initial concentration a, and the ratio ξ'/ξ takes the place of the relative initial concentration b/a.

The numerical application of (11) is straightforward. Experiment gives a, b, c, d and ξ, and hence K is calculated. Since, from (4),

$$\xi + \xi' = \frac{K(a+b)+(c+d)}{K-1} \quad . \qquad . \qquad . \qquad . \quad (12)$$

ξ' follows immediately, and therefore n. The course of the experiment gives correlated values of λ and ϑ, from which, with tables of $\psi(n)$, $k-k'$ is calculated.

§ 4. Maximum Transformation and Minimum Time.

It is clear from (8) that the end-point ξ depends upon the initial concentrations. Taking the case in which the reaction proceeds in the forward direction, we may examine the influence upon ξ of the presence of C and D by regarding the parabola $k(a-x)(b-x)$ as fixed and cut by the variable parabola $k'(c+x)(d+x)$ for different values of c and d. Since $kab > k'cd$ it is clear that the greatest value of ξ in so far as it depends upon c and d is given by $c=d=0$. Under these conditions, writing $b=\mu a$, we find

$$\xi = a\frac{K(\mu+1)-\sqrt{K^2(\mu-1)^2+4K\mu}}{2(K-1)} \quad . \qquad . \qquad . \quad (13)$$

This is a monotonic increasing function of μ, hence the larger b is compared with a the greater will be the fraction of a, ultimately transformed.

Also

$$n = \frac{\xi'}{\xi} = \frac{K(\mu+1) + \sqrt{K^2(\mu-1)^2 + 4K\mu}}{K(\mu+1) - \sqrt{K^2(\mu-1)^2 + 4K\mu}} \qquad . \qquad . \quad (14)$$

Therefore n increases with μ. And since $\psi(n)$, for any given λ, diminishes as n increases, it follows that ϑ diminishes as μ increases. Hence excess of b compared with a means not only increased ultimate transformation, but also a speedier reaction.

9th August 1922.

A STUDY IN CHARCOAL.

BEING A RESEARCH ON CHARCOALS MADE FROM EXOTIC WOODS GROWN IN THE UNION OF SOUTH AFRICA.

By W. S. H. CLEGHORNE, D.Sc. (Edin.), A.M.I.Mech.E.,
Government Experiment Station, Potchefstroom, South Africa.

(With five Text-figures.)

The various samples of charcoal were supplied by the Forest Department in five-bag lots, together with the following details with regard to their manufacture, etc. :—

Eucalyptus resinifera :

This charcoal was burned by the " Fort Cunynghame method " described on pp. 6–8 of " Bulletin No. 1 " of 1919, compiled by Mr. J. J. Kotze, B.A., B.Sc., Acting Forest Research Officer of the Forest Department, Union of South Africa. See also pp. 9, 11, and 12 of the same " Bulletin," revised in March 1920. Further particulars are—

Age of wood . . . . 8 years.
Size . . . . . . 2 inches to 6 inches diameter.
Degree of dryness . . . Green.
Carbonised with bark on.
Manufactured at Jessievale, P.O. Vosmansbeacon, *via* Carolina, Ermelo District, November 1919.

Eucalyptus viminalis :

Method of burning . . . In cast-iron retort.
Age of wood . . . . 9 years.
Size . . . . . . 3 inches to 5 inches diameter.
Degree of dryness . . . Half-dry.
Carbonised with bark on.
Manufactured at Pan Plantation, Middelburg, Transvaal, January 1920.

Eucalyptus saligna :

Method of burning . . .	Fort Cunynghame.
Age of wood . . .	6 years.
Size	3 inches to 5 inches diameter.
Degree of dryness . . .	Very dry.

Manufactured at Jessievale, September 1919.

Eucalyptus sideroxylon :

Method of burning . . .	In cast-iron retort.
Age of wood . . .	11 years.
Size	4 inches to 5 inches diameter.
Degree of dryness . . .	Half dry.

Carbonised with bark on.
Manufactured at Pan, Middelburg, Transvaal, August 1919.

Eucalyptus tereticornis :

Method of burning . . .	In cast-iron retort.
Age of wood . . .	12 years.
Size	3 inches to 5 inches diameter.
Degree of dryness . . .	Half dry

Carbonised with bark on.

Manufactured at Pan, September 1919.

Eucalyptus maidenii :

Method of burning . . .	In cast-iron retort.
Age of wood . . .	9 years.
Size	3 inches to 5 inches diameter.
Degree of dryness . . .	Half dry.

Carbonised with bark on,

Manufactured at Pan, January 1920.

Pinus insignis (Pan) :

Method of burning . . .	In cast-iron retort.
Age of wood . . .	9 years.
Size	3 inches to 5 inches diameter.
Degree of dryness . . .	Half dry.

Carbonised with bark on.

Manufactured at Pan, January 1920.

Pinus insignis (Fort Cunynghame) :

Pinus pinaster (Fort Cunynghame) :

> Method of burning : The method of manufacture was as given in
> Schlich's " Manual of Forestry," vol. v, pp. 708–9 (pp. 540–2,
> second edition), the wood being cut to 4-foot billets. Owing
> to a sudden gale on a Sunday, although the kilns were protected
> by a wattle screen, both kilns fired badly, and it was with some
> difficulty that any portion was saved.
>
> Age of wood . . . . 29 years.
> Size . . . . . . 3 inches to 5 inches diameter.
> Degree of dryness . . . Quite dry.
> Carbonised with bark on.
>> Manufactured at Fort Cunynghame Plantation (Toise River
>> Station), November 1919.

Pinus taeda :

> Method of burning . . . " Fort Cunynghame " method.
> Age of wood . . . . 9 years.
> Size . . . . . . 2 inches to 4 inches diameter.
> Degree of dryness . . . Very dry.
> Carbonised with bark on.
>> Manufactured at Jessievale, December 1919.

Cupresses lusitanica :

> Method of burning . . . " Fort Cunynghame " method.
> Age of wood . . . . 7 years.
> Size . . . . . . 2 inches to 4 inches diameter.
> Degree of dryness . . . Very dry (and sound).
> Carbonised with bark on.
>> Manufactured at Jessievale, November 1919.

Acacia decurrens, var. *mollis* (Black Wattle) :

> Method of burning . . . " Fort Cunynghame " method.
> Age of wood . . . . 7 years.
> Size . . . . . 2 inches to 4 inches diameter,
>> poles 20 feet to 25 feet long.
> Degree of dryness . . . Very dry.
> Carbonised with bark off.
> The wood before conversion into charcoal lay in the plantation fully
> exposed to all weather conditions.
>> Manufactured at Jessievale, August 1919.

Acacia cyclopis :

Acacia saligna :

Method of burning : The pieces were stacked in a conical form measuring 15 feet diameter at the base and 7½ feet high. The stack or kiln was then covered with green cyclopis branches free from seed pods. This thatch of green branches was then entirely covered with sand 3 inches thick. The fire was started at the top of the kiln and drawn towards the base by means of vent spaces. When the kiln was finished it was covered with another layer of sand beaten down firmly, and left for two days to cool.

Age of wood   .   .   .   . Freshly cut.

Size .   .   .   .   .   . ½ inch to 3½ inches diameter by 2½ feet long.

Manufactured at Eerste River Forest Reserve, Cape Peninsula.

OBJECTS AND METHODS OF THE TESTS.

The object of the research was to endeavour to classify the different charcoals by the following methods :—

1. Proximate analysis of the charcoal.

2. Measurement of the fuel consumption per brake horse-power hour on suction-gas engine trial at constant given load, for six hours' run.

3. Analysis of the gas from the gas producer while the engine was on the trial mentioned under 2.

4. Measurement of the weight of each charcoal per given volume.

5. The discovery of any consistent relationships between the various quantities measured.

Beyond these initial objects, others which became apparent as the work progressed were pursued.

ENGINE TRIALS.

The engine used was a " P " type " National " suction-gas engine, drawing gas from a " B "-size " National " producer. Every precaution was taken to have conditions as uniform as possible over all the trials. For the purposes of these trials, a flexible water-seal joint was inserted in the pipe conveying the gas from the producer to the scrubber, and the former was placed on the platform of a weighing-machine so that the fuel consumption could be determined with the maximum degree of accuracy. The need of great accuracy in measuring the fuel consumption will be clear when it is stated that in some cases the total fuel consumption was less than sixty pounds. Further, the engine was run for at least one hour on the test

load before the commencement of the six hours' trial, and stoking was arranged to occur a quarter of an hour before the commencement, and the same time before the end, of the trial, so that conditions in the producer might be as nearly as possible the same at the beginning and end of the trial.

The engine, when new, was capable of delivering 11 B.H.P. at the altitude of Potchefstroom, viz. 4430 feet above sea-level, but, being somewhat worn by the date of the trials, the maximum load that it was considered safe to expect the engine to maintain on trial was about $7\frac{1}{2}$ B.H.P., and at approximately that load each trial was run. A water-cooled Prony brake was used, and indicator diagrams were taken at regular intervals during each trial in order to keep in touch with the working of the engine. The cams on the half-time shaft were considerably worn. In the accompanying indicator diagrams this is most clearly shown by the indication of late opening of the exhaust valve.

TESTS OF THE PRODUCER GASES.

The gas samples were taken after the gas had passed through the scrubber, so the gas analysed was such as was actually supplied to the engine. In this connection, however, it should be borne in mind that some of the carbon dioxide and hydrocarbons in the gases as they leave the producer would be likely to be absorbed by the water in the scrubber.

For the gas analyses an Orsat-Lunge gas-analysis apparatus, fitted with a palladium-asbestos tube, was used.

In all but one case—that of *Eucalyptus viminalis,* in which the gas sample was drawn over a long period—two samples of gas were taken and analysed for each charcoal tested. In the case of duplicate engine trials this was done for some of the Eucalypts (which were tested early in the course of the research) in only one of the duplicate trials. Later on, however, when found to be advisable, it was done in all cases, the first gas sample being taken during the first hour of the engine trial, and the second sample during the fifth hour. Each sample of the gas was drawn over a period of about twenty-five minutes. The gas samples were collected over mercury. Every precaution was taken to secure accurate results in the gas analyses, to each of which from $2\frac{1}{2}$ to 3 hours were devoted. Thus, after the carbon monoxide had been absorbed in the carbon-monoxide absorption pipette, which contained acid solution of cuprous chloride, the residual gases were taken back into the carbon-dioxide absorption pipette in order to find if any acid fumes were present. Further, the palladium-asbestos tube and adjoining parts were allowed to cool off completely before measuring the contraction of the gases after they had been passed through the tube.

While the author was awaiting the arrival of apparatus from abroad, he made proximate analyses of the samples of charcoal as they arrived.

An air-dried sample of each charcoal was prepared by finely powdering it, heating it for an hour to a temperature of 55 degrees Centigrade, and then spreading it out exposed to the atmosphere of the room, but protected from dust, for two days.

The following results were obtained :—

TABLE No. 1.

Proximate Analyses of Charcoals when received.

	Per Cent. Moisture.	Per Cent. Volatile Matter.	Per Cent. Fixed Carbon.	Per Cent. Ash.
Eucalyptus resinifera . . .	7·94	14·40	76·47	1·19
Eucalyptus viminalis . . .	5·85	18·91	72·87	2·37
Eucalyptus saligna . . .	2·89	5·60	90·59	0·92
Eucalyptus sideroxylon . .	3·74	19·29	75·37	1·60
Eucalyptus tereticornis . .	3·71	21·35	73·82	1·12
Eucalyptus maidenii . .	8·27	8·50	80·71	2·52
Pinus insignis (Pan) . . .	6·81	17·45	74·29	1·45
Pinus insignis (Fort Cunynghame)	6·58	15·76	76·47	1·19
Pinus pinaster	9·04	11·79	78·25	0·92
Pinus taeda	7·81	10·71	80·14	1·34
Cupressus lusitanica . . .	4·51	10·20	83·84	1·45
Acacia decurrens, var. *mollis* (Black Wattle)	1·86	9·42	88·08	0·64
Acacia cyclopis	3·44	31·10	62·82	2·64
Acacia saligna	5·00	8·80	83·77	2·43

The method employed in making the above proximate analyses, as well as those of the charcoals as fed to the producer during the engine trials, was as follows :—

Moisture Test.—One or two grams of the test sample were placed in a glass weighing-bottle, weighed on a chemical balance, heated in a dry-air oven to 105 degrees Centigrade for half an hour, stoppered and placed in a desiccator till cool, then weighed again. This was repeated, the sample being heated for half an hour each time till its weight began to increase. The minimum weight recorded was used in determining the moisture contents. To be quite accurate, column 1 of the preceding table, and column 8 of Table No. 2, should be headed : "Per cent. moisture plus occluded gases driven off at 105 degrees Centigrade."

Table No. 2.

1	2	3	4						5	6	7	8	9	10	11
Charcoal.	Date of Engine Trial.	Fuel Consumption per B.H.P. Hour, lbs.	Gas Analysis.						Cal. Value of Gas in B.T.U. per Cubic Foot.	Mean Cal. Value of Gas in B.T.U. per Cubic Foot.	Mean Temperature in Engine-room. °F.	Fuel as fed to Producer.		Weight of Ground Fuel per 47 Cubic Inches.	Proportional to Volume of Fuel consumed per B.H.P. Hour.
			CO_2	O_2	CO	CH_4	H_2	N.				Occluded Gases Plus Moisture. Per Cent.	Volatile Matter. Per Cent.	Grams.	
Euc. resinifera	18 Nov. '20 (afternoon)	1·38	9·1	0·6	17·5	2·9	19·0	50·9	143·3	140·8	89				
			10·8	0·5	14·5	3·6	18·5	52·1	138·4			5·84	9·53	213·0	6·25
Euc. viminalis	15 Oct.	1·39	7·2	2·1	19·2	1·4	21·0	49·1	140·5	..	91				
" "	10 Nov.	1·35	7·1	0·9	20·1	2·7	19·5	49·7	151·9	..	90	4·20	17·05	204·8	6·68
Euc. saligna	22 Oct.	1·52	8·3	0·8	18·9	1·5	16·5	52·0	133·1	..	87				
" "	12 Nov.	1·53	10·1	1·0	15·6	2·7	18·2	52·4	132·3	135·5	89	4·64	7·92	187·4	8·14
			10·9	1·1	14·3	3·4	19·5	50·8	138·7						
Euc. sideroxylon	29 Oct.	..	6·7	0·8	22·8	1·2	20·5	48·0	149·4	..	76				
" "	23 Nov.	1·36	8·2	1·5	17·1	2·9	19·6	50·7	143·6	144·7	89·5	6·36	21·98	212·0	6·42
			8·8	1·9	16·6	3·4	19·3	50·0	145·9						
Euc. tereticornis	4 Nov.	1·45	6·6	0·9	21·3	2·2	18·1	50·9	146·9	..	87				
" "	16 Nov.	1·48	6·8	0·4	20·9	3·0	17·4	51·5	151·2	150·5	85	4·43	17·48	225·3	6·50
			9·8	0·7	17·6	2·8	21·3	47·8	149·8						
Euc. maidenii	25 May '21	1·46	6·4	2·0	20·5	1·7	13·9	55·5	127·1	136·5	60·5	6·32	9·49	216·8	6·74
			8·2	1·6	19·0	2·5	19·5	49·2	146·0						
P. insignis (Pan)	19 April	1·71	5·3	0·9	24·2	1·6	13·6	54·4	137·9	143·4	79·5	6·48	17·53	129·7	13·20
			7·8	1·2	20·6	1·6	21·6	47·2	148·9						
P. insignis (Fort C.)	26 April	1·48	7·0	2·5	21·5	0·8	16·5	51·7	129·4	133·8	67	7·71	11·06		
			9·0	1·2	18·5	1·2	21·7	48·4	138·2						
"	17 May	1·52	8·6	1·1	19·3	0·8	18·9	51·3	128·9	131·6	64			136·2	11·00
			8·3	1·4	19·2	1·5	18·6	51·0	134·4						
Pinus pinaster	18 May	2·17	6·1	1·2	22·4	1·1	11·6	57·6	121·1	127·0	67	7·91	13·14		
			9·9	1·3	16·9	1·8	19·8	50·3	132·9						
" "	23 May	2·10	7·4	0·8	21·1	1·3	16·0	53·4	131·4	137·0	59			173·7	12·26
			9·1	1·1	18·4	2·3	19·7	49·4	142·6						
Pinus taeda	14 June	1·66	7·4	1·0	19·7	2·6	18·0	51·3	145·0	142·5	58	7·54	17·03	121·6	13·65
			9·6	1·6	15·3	3·2	19·5	50·8	140·1						
Cup. lusitanica	16 June	1·51	6·5	1·4	20·1	2·6	16·2	53·2	141·1	141·5	59·3	4·77	12·93	103·1	14·62
			10·4	1·7	14·3	3·2	21·3	49·1	141·9						
Black Wattle	20 June	1·55	8·0	0·8	22·0	0·0	19·4	49·8	131·9	137·1	60	6·30	9·87	198·1	7·88
			8·4	0·8	21·8	0·0	23·2	45·8	142·3						
" "	23 June	1·57	8·1	0·7	21·3	0·4	19·0	50·5	132·2	131·9	54				
			9·7	1·0	18·9	0·5	21·3	48·6	131·6						
Acacia cyclopis	27 June	1·76	6·5	0·4	23·8	0·5	18·3	50·5	139·6	149·8	61	5·84	31·61	271·9	6·48
			7·7	0·9	22·9	1·1	24·3	43·1	159·9						
Acacia saligna	30 May	1·29	6·1	1·4	21·3	1·8	15·4	54·0	135·1	146·9	59	5·31	14·68	245·0	5·27
			6·9	0·7	21·9	2·7	19·8	48·0	158·7						
Natal anthracite	30 June	1·71	7·1	1·2	17·9	0·7	17·4	55·7	118·8	114·5	62	4·59	6·15 Ash= 16·06	674·2	2·51
			11·1	0·5	16·2	1·0	18·9	52·3	110·2						
" "	6 July	1·68	6·2	1·2	19·1	1·0	17·3	55·2	125·5	124·7	50				
			10·4	0·3	16·8	1·2	18·8	52·5	123·9						

(Column 8 annotations: Euc. rows — "Average Moisture 5·30%"; P. insignis / Pinus rows — "Average Moisture 7·41%"; Wattle / Acacia rows — "Average Moisture 5·89%".)

Test for Volatile Matter.—One or two grams of the sample was placed in a platinum crucible with lid, weighing about 16½ grams. The crucible was heated by means of a Bunsen flame, and allowed to cool, alternately, each time a higher temperature being reached before particles of charcoal began to be driven off. Then the crucible was heated over the full flame of a Bunsen burner for six minutes. The crucible was supported on a triangle of platinum wire with its bottom 6 to 8 centimetres above the top of the burner, the flame being 20 centimetres high when the crucible was removed. The tests were made in a place free from draughts. The procedure recommended by the Committee on Coal Analysis, " Journal of the American Chemical Society," 1899, vol. xxi, was followed as closely as possible with the above-mentioned modification, *i.e.* alternate heating and cooling with gradually-increasing temperature till the sample could stand the desired temperature without particles being driven off. The loss of weight represented the amount of volatile matter and moisture in the sample. Subtracting the known weight of moisture gave the weight of volatile matter.

Ash Test.—The sample was intensely heated in the open crucible until all the carbon was burned away.

Fixed Carbon.—The percentage of fixed carbon is the difference between 100 and the sum of the percentage weights of moisture, volatile matter, and ash.

Analyses of Charcoals as fed to Producer.—The percentages of moisture plus occluded gases driven off at 105 degrees Centigrade, and of volatile matter, in the charcoals as fed to the producer during the engine trials, are given in columns 8 and 9, Table No. 2. For these analyses representative samples were taken, as the charcoal was being fed to the producer, quickly ground in a mortar, and kept in sealed bottles till analysed. Between these analyses and the first-made proximate analyses, the five-bag samples of charcoal were stored in a dry shed for nine months or, in some cases, longer, depending on the order of the reception of the samples and the testing thereof.

Thus, before the second analyses and the engine trials the charcoals had time to reach conditions that were probably steady. This view is borne out by the comparatively small differences (in column 8, Table No. 2) in the percentages of moisture plus occluded gases in the different species of each genus. Further, as shown by these percentages, the Pines sort themselves out from the Eucalypts and Acacias, the average percentage moisture plus occluded gases for the three genera being as follows :—

TABLE No. 3.

Genus.	Average Percentage of Moisture, plus Occluded Gases driven off at 105 Degrees Centigrade.
Eucalypts	5·30
Acacias	5·82
Pines	7·41

This figure in the case of the Pines is higher than for the other genera, doubtless on account of the greater volume, per unit weight, of the Pines.

A representative sample of the Natal anthracite as fed to the producer during the engine trial was also analysed with the result (also given in columns 8 and 9, Table No. 2) :—

TABLE No. 4.

Per Cent. Moisture plus Occluded Gases driven off at 105 Degrees Centigrade.	Per Cent. Volatile Matter.	Per Cent. Fixed Carbon.	Per Cent. Ash.
4·59	6·15	73·20	16·06

The high percentage of ash is characteristic of South African coals.

Probable Accuracy of the Engine Trials and Gas Analyses.—In the case of seven different fuels it was possible to run engine trials in duplicate. The following table of results, and calculated per cent. difference between the fuel consumption in any two engine trials with the same fuel, shows that in no such case is the difference more than 3·2 per cent.

TABLE No. 5.

Table showing Accuracy of Duplicate Engine Trials.

Kind of Fuel.		Fuel Consumption per Brake Horse-power Hour in Lbs.	Per Cent. Difference in Fuel Consumption.	Lower Calorific Value of Gas in British Thermal Units per Cubic Foot.
Eucalyptus viminalis	1st trial	1·39	2·9	140·5
,, ,,	2nd ,,	1·35 *l*		151·9 *h*
Eucalyptus saligna	1st trial	1·52	0·65	133·1
,, ,,	2nd ,,	1·53		135·5
Eucalyptus tereticornis	1st trial	1·45	2·0	—
,, ,,	2nd ,,	1·48		150·5
Pinus insignis (Fort C.)	1st trial	1·48	2·6	133·8
,, ,, ,,	2nd ,,	1·52 *h*		131·6 *l*
Pinus pinaster	1st trial	2·17	3·2	127·0
,, ,,	2nd ,,	2·10 *l*		137·0 *h*
Black Wattle	1st trial	1·55	1·3	137·1
,, ,,	2nd ,,	1·57 *h*		131·9 *l*
Natal Anthracite	1st trial	1·71	1·7	114·5
,, ,,	2nd ,,	1·68 *l*		124·7 *h*

That conditions were kept very constant over a number of engine trials is evidenced from the fact, to take only one instance, that duplicate tests of *Eucalyptus viminalis* charcoal were made on 15th October 1920 and 10th November 1920, respectively, three engine trials with other charcoals as fuel having been run between these dates. Yet the difference in the fuel consumption of *Eucalyptus viminalis* charcoal between that on 15th October and that on 10th November was only 2·9 per cent.

As a further indication of the accuracy of both the engine trials and the gas analyses, it will be noticed from the above table (No. 5) that when in any one pair of duplicate trials the fuel consumption is lower for the second trial than for the first, then the calorific value of the gas is higher for the second than for the first, and *vice versa.* This has been indicated by the insertion of the letters *h* (high) and *l* (low) in the table.

In the case of *Eucalyptus saligna*, the fuel consumption in each one of the duplicate trials are substantially equal, as are also the calorific values of the gas.

Differences in the quantity of gas produced per pound of fuel consumed may, of course, have affected the results, but such differences could only be slight—because the trials were run as similarly as possible. Evidently this has been the case, as such differences have not been of sufficient magnitude to obscure the above-mentioned rational relationship of high calorific value of the gas corresponding with low fuel consumption. It should here be mentioned that in each case the calorific value of the gas was calculated from the figures of the gas analysis, the "lower" calorific value being taken.

Effect of Duration of Run on Composition of Gas.—As already mentioned, two samples of gas were drawn for analysis, the first during the first hour of the trial run, and the second during the fifth hour. Reference to column 4, Table No. 2, shows that, in general, the later sample contained more carbonic acid gas, less carbon monoxide, more hydrogen, more methane, and less nitrogen than the earlier sample.

Take, for example, the figures for *Pinus pinaster*, 18th May 1921, comparing the analysis of the second sample of gas with that of the first, notwithstanding the great increase in carbonic-acid gas, from 6·1 to 9·9 per cent., the hydrogen gas has increased from 11·6 to 19·8 per cent., while the carbon monoxide has decreased from 22·4 to 16·9 per cent. These changes are explained by the circumstance that carbon monoxide at a high temperature decomposes steam, so that part of that gas, which would otherwise have appeared in the mixture, has disappeared, forming carbonic-acid gas and hydrogen according to the following equation :—

$$CO + H_2O = CO_2 + H_2.$$
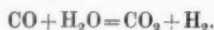
Since the temperature of the producer in the fifth hour of the engine trial

was higher than in the first, one would expect the second sample of producer gas to contain more carbonic acid gas, more hydrogen, and less carbon monoxide than the sample taken during the first hour. This expectation is justified by the results of the author's analyses in practically every case.

No doubt, also, the increase in methane in the second gas sample over that in the first can be ascribed to the higher temperature of the producer towards the end of the trial, which increases the velocity of the reactions forming methane.

It happened, quite fortuitously, in the case of two duplicate engine trials, that one trial was run in cool weather and the other (check) trial in hot weather, the charcoals consumed being *Eucalyptus resinifera* and *Eucalyptus sideroxylon* respectively. Tabulating the production of methane and the mean engine-room temperature during the trial, we have :—

TABLE No. 6.

Charcoal used in Engine Trial.	Percentage of Methane in Producer Gas.	Mean Temperature of Engine-room.
Eucalyptus resinifera , , , .	0·7 (first hour) 0·6 (fifth ,)	} 73 degrees Fah.
Eucalyptus resinifera , , ,	2·9 (first hour) 3·6 (fifth ,)	} 89 degrees Fah.
Eucalyptus sideroxylon , , ,	} 1·2	76 degrees Fah.
Eucalyptus sideroxylon , , ,	2·9 (first hour) 3·4 (fifth ,)	} 89·5 degrees Fah.

The above results seem to indicate that at higher engine-room temperatures more methane is produced than at lower engine-room temperatures. Since the tests were not arranged with reference to this point, more definite indications cannot be given. To settle the matter, it would be necessary to run a series of trials in the winter and an exactly similar series, with the same samples of charcoal, in the summer-time.

Relationship between the Quantity of Volatile Matter in the Charcoal and the Calorific Value of the Gas.—The following table appears to indicate that when the per cent. weight of volatile matter in a charcoal is high, the

3

calorific value of the producer gas per cubic foot at normal temperature and pressure is also high and *vice versa*.

TABLE No. 7.

Eucalypts.

Kind of Charcoal.	Per Cent. Weight of Volatile Matter in the Charcoal.	Lower Calorific Value of Producer Gas in British Thermal Units per Cubic Foot.
Eucalyptus saligna	7·92	135·5
Eucalyptus maidenii	9·49	136·5
Eucalyptus resinifera	9·53	140·8
Eucalyptus viminalis	17·05	146·2
Eucalyptus tereticornis	17·48	150·5
Eucalyptus sideroxylon	21·98	144·7

In the above table, with the exception of *Eucalyptus viminalis*, only the results of these trials are taken in which the gas samples were drawn during the first and fifth hour respectively. The values for *Eucalyptus viminalis* were accepted, because the gas samples were drawn over a long period, extending over nearly the whole of the trial.

TABLE No. 8.

Pines.

Kind of Charcoal.	Per Cent. Weight of Volatile Matter in the Charcoal.	Lower Calorific Value of Producer Gas in British Thermal Units per Cubic Foot.
Pinus insignis (Fort Cunynghame)	11·06	132·7
Pinus pinaster	13·14	132·0
Pinus taeda	17·03	142·5
Pinus insignis (Pan)	17·53	143·4

TABLE No. 9.

	Acacias.	
Kind of Charcoal.	Per Cent. Weight of Volatile Matter in the Charcoal.	Lower Calorific Value of Producer Gas in British Thermal Units per Cubic Foot.
Acacia decurrens, var. *mollis* (Black Wattle) . .	9·87	134·5
Acacia saligna . . .	14·68	146·9
Acacia cyclopis . .	31·61	149·8

The above relationship is shown graphically by the curves given in fig. 1. It will be noticed that the Pines again clearly separate themselves from the
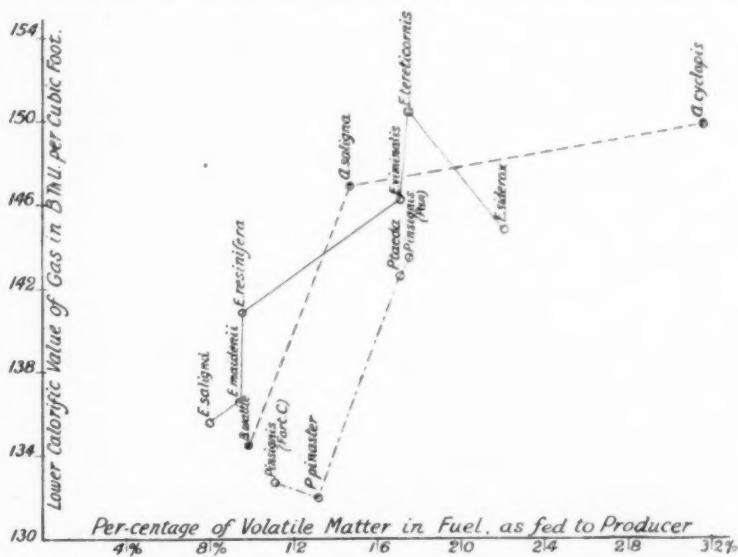
Fig. 1.

Eucalypts and Acacias. The three curves are remarkably similar, showing approximately the same rate of increase of calorific value of the producer gas with increasing percentage weight of volatile matter in the charcoal.

Eucalyptus sideroxylon shows a lower calorific value of the gas than might be expected, no doubt due to the very thick bark of this tree (really the point representing *Eucalyptus sideroxylon* lies on quite another curve, viz. that of the " ironbarks ") ; but the curve of the Acacias almost strikes an average between the points on the Eucalypt curve, the rate of increase in the calorific value of the gas being high up to a certain point—represented by *Acacia saligna* in the Acacia curve—and then lower after that point has been passed.

Rich Gas shown by the Indicator Diagrams.—The difference between a rich producer gas, *i.e.* one of high calorific value, and a poor one was clearly shown by the indicator diagrams and also by the number of explosions. In order to illustrate this, average indicator cards for *Acacia cyclopis*

Figs. 2 and 3.

charcoal and anthracite (which gave the poorest gas of all) are reproduced in figs. 2 and 3 respectively. The indicator piston, in the case of the *Acacia cyclopis* charcoal, was driven hard against the " stop," the spring not being strong enough for this gas. The strongest spring available, $\frac{1}{100}$, was used in each case. The higher expansion line (with " weak spring " oscillations) is noticeable in the case of the *Acacia cyclopis* charcoal. The total number of explosions during the six hours' test were :—
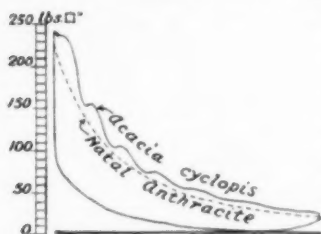
> *Acacia cyclopis* . . . 36,253
> Anthracite . . . 40,700

Volume of Gas produced per Pound of Charcoal.—Chiefly on account of the expense involved, direct measurement of this could not be carried out, but relative quantities were calculated as follows :—

$$
\begin{Bmatrix} \text{B.Th.U.'s per} \\ \text{B.H.P. hour} \\ \text{sent to engine} \end{Bmatrix} = \begin{Bmatrix} \text{Fuel consump-} \\ \text{tion per B.H.P.} \\ \text{hour in lbs.} \end{Bmatrix} \times \begin{Bmatrix} \text{Quantity of} \\ \text{gas per 1 lb.} \\ \text{of fuel in c. ft.} \end{Bmatrix} \times \begin{Bmatrix} \text{Calorific} \\ \text{value of the} \\ \text{gas per c. ft.} \end{Bmatrix}
$$

therefore :

$$
\begin{matrix} \text{Quantity of gas per 1 lb. of fuel,} \\ \text{in c. ft.} \end{matrix} = \dfrac{\text{B.Th.U.'s per B.H.P. hour sent to engine.}}{\begin{Bmatrix} \text{Fuel consump-} \\ \text{tion per B.H.P.} \\ \text{hour in lbs.} \end{Bmatrix} \times \begin{Bmatrix} \text{Calorific} \\ \text{value of the} \\ \text{gas per c. ft.} \end{Bmatrix}}
$$

But the numerator on the right-hand side of this equation is constant since the engine ran on the same load and, as far as possible, under the same conditions in each trial, hence

$$\text{Quantity of gas per 1 lb. of fuel, in c. ft.} = \left\{ \frac{K}{\left\{\begin{array}{c}\text{Fuel consump-}\\ \text{tion per B.H.P.}\\ \text{hour in lbs.}\end{array}\right\} \times \left\{\begin{array}{c}\text{Calorific}\\ \text{value of the}\\ \text{gas per c. ft.}\end{array}\right\}} \right.$$

In order to obtain suitable relative figures, the constant K was taken equal to 1000, and the relative quantities of gas per one pound of fuel calculated, with the following results :—

TABLE No. 10.

Charcoal	Quantity of Gas per 1 lb. of Charcoal Proportional to	Lower Calorific Value of the Gas. B.Th.U.'s per Cubic Foot.
Eucalyptus resinifera .	5·15	140·8
Eucalyptus viminalis .	5·00	146·2
Eucalyptus saligna . .	4·88	135·5
Eucalyptus sideroxylon .	5·08	144·7
Eucalyptus tereticornis .	4·53	150·5
Eucalyptus maidenii . .	5·02	136·5
Pinus insignis (Pan) .	4·08	143·4
Pinus insignis (Fort Cunynghame) . .	5·02	132·7
Pinus pinaster . . .	3·55	132·0
Pinus taeda . . .	4·23	142·5
Cupressus lusitanica . .	4·68	141·5
Acacia decurrens, var. *mollis* (Black Wattle) . .	4·77	134·5
Acacia cyclopis . .	3·79	149·8
Acacia saligna . . .	5·27	146·9
Natal Anthracite . .	4·93	119·6

The figures in the above table have been plotted, giving the curves of fig. 4.

Here, again, the Acacia curve follows that of the Eucalypts very closely, while the Pine curve, of course, is separated on account of the lower calorific values of the pines as a whole.

The similarity of all three curves is noteworthy, all being concave towards the left, showing that at low calorific values of the gas the volume of gas produced per pound of charcoal increases as the richness of the gas increases, but that at higher calorific values of the gas the volume of gas per pound of charcoal decreases as the richness of the gas continues to increase.

The best charcoals from this point of view are, of course, those that are furthest away from the origin of co-ordinates.

Relative Volumes of the Charcoals per Unit Weight.—In order to arrive,
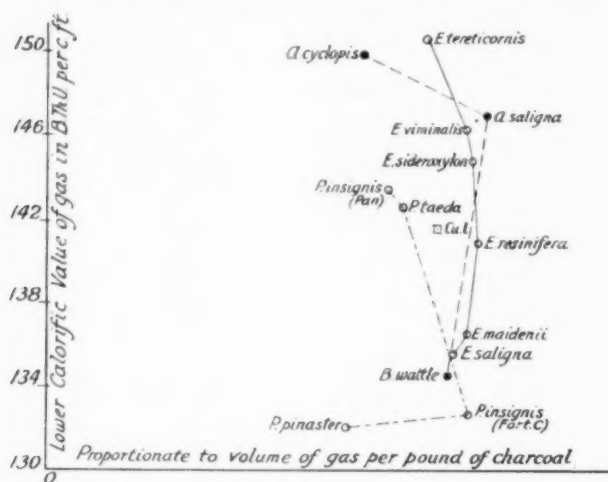
Fig. 4.

in a practical way, at the relative volumes of the charcoals, representative samples were roughly ground in a mortar and passed through a sieve with ⅓-inch meshes. The charcoal that passed this sieve then had the dust screened out through a sieve with ₁⅟₆-inch meshes, and was weighed. A tin mug 4 inches diameter by 3¾ inches deep inside (capacity 47 cubic inches) was filled with the sample of charcoal to be weighed, the latter being gently shaken down and struck off level with the top edge of the mug. Each charcoal was in practically the same condition as to moisture, etc., as when fed to the producer during the engine trials. The mug was filled three times with a different portion of the sample, and three weighings made for each charcoal. The Natal anthracite was put through the same test.

Note that the only wood that was carbonised with the bark off was *Acacia decurrens*, var. *mollis*. This would be done in practice, the

bark being used for the manufacture of wattle-bark extract for tanning purposes.

The following results were obtained :—

Kind of Charcoal.	1st Weighing.	2nd Weighing.	3rd Weighing.	Mean of Three Weighings.
	Grams.	Grams.	Grams.	Grams.
Eucalyptus resinifera .	212·7	214·7	211·6	213·0
Eucalyptus viminalis .	205·7	202·6	206·2	204·8
Eucalyptus saligna .	185·0	187·3	190·0	187·4
Eucalyptus sideroxylon .	212·6	205·0	218·4	212·0
Eucalyptus tereticornis .	222·1	228·6	225·3	225·3
Eucalyptus maidenii .	215·0	218·7	216·6	216·8
Pinus insignis (Pan) .	124·3	129·9	134·9	129·7
Pinus insignis (Fort Cunynghame) . .	131·4	136·2	141·0	136·2
Pinus pinaster . .	167·7	176·0	177·5	173·7
Pinus taeda . . .	127·4	118·2	119·1	121·6
Cupressus lusitanica .	102·6	101·9	104·7	103·1
Acacia decurrens, var. *mollis* (Black Wattle) .	194·2	200·1	199·9	198·1
Acacia cyclopis . .	272·7	271·0	271·9	271·9
Acacia saligna . .	249·8	238·8	246·3	245·0
Natal Anthracite . .	674·7	665·7	682·1	674·2

Having figures of the weight of each fuel per given volume, and also the fuel consumption per B.H.P. hour in pounds, figures proportional to the volume of fuel consumed per B.H.P. hour can be calculated. This has been done, and the results tabulated in column 11, Table No. 2. These figures were then plotted against the corresponding fuel consumption in pounds per B.H.P. hour, giving the graphs shown in fig. 5.

Once more part of the Acacia curve practically strikes an average through the points of the Eucalypt curve. Due mostly to the lesser weight per unit volume of the Pines, the curve of these charcoals is well separated from the Eucalypt and Acacia curves.

The curves given in fig. 6, namely, quantities proportional to volume of producer gas (per pound of charcoal) multiplied by the calorific value of the gas per cubic foot plotted against weight of samples of ground charcoal

per 47 cubic inches, again show a resemblance between the curves of the different genera.

In each genus volume of gas multiplied by its calorific value per cubic
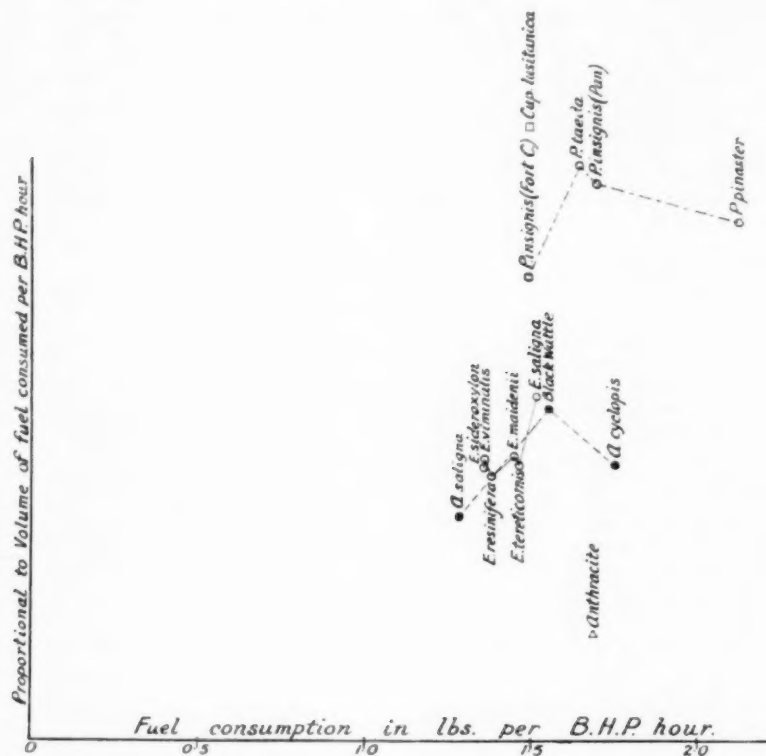

Fig. 5.

foot increases at first with increase in the " density " of the charcoal, and then falls off again after reaching a maximum.

Plotting the volume of gas produced per pound of charcoal against weight of ground charcoal per 47 cubic inches gave very similar curves to those in fig. 6, showing that this volume is the preponderating factor.

The two preceding paragraphs may be summed up by saying that, in each genus, charcoals of *medium* weight per unit volume produce the greatest volume of gas per pound of charcoal, and also give the highest

values of :—volume of gas per pound of charcoal multiplied by the calorific
value of the gas per cubic foot.
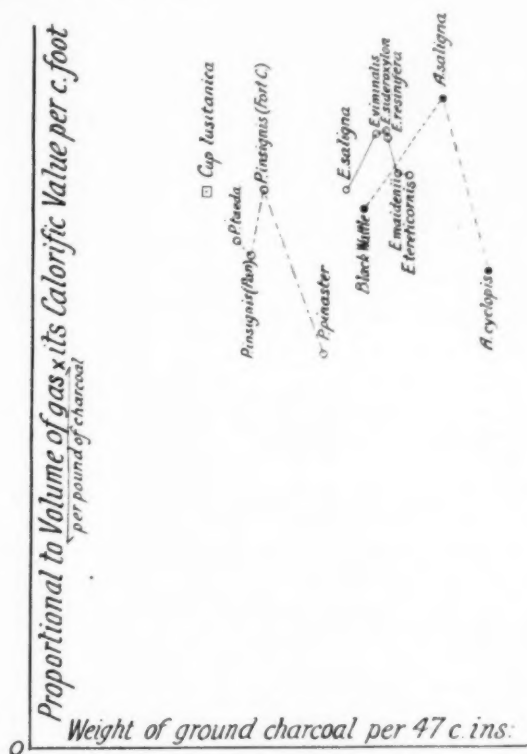
Fig. 6.

From the information in the preceding part of this thesis, the following
has been extracted :—

The charcoals which gave the richest producer gas in each genus are :
1. *Eucalyptus tereticornis.   Acacia cyclopis.   Pinus insignis* (Pan).
The charcoals of which the least weight was consumed per brake horse-
power hour are :

2. *Eucalyptus sideroxylon* ⎫ nearly   *Acacia saligna.   Pinus insignis*
   Eucalyptus viminalis   ⎬ equal.   (Fort C.).
   Eucalyptus resinifera   ⎭

The charcoals that gave the greatest volume of gas per pound of charcoal (calculated from 1 and 2) in each genus are :

3. *Eucalyptus resinifera.   Acacia saligna.   Pinus insignis* (Fort C.).

The charcoals of which the least volume was consumed per brake horse-power hour are :

4. *Eucalyptus resinifera* ⎫
   Eucalyptus sideroxylon ⎪
   Eucalyptus tereticornis ⎬ nearly
   Eucalyptus viminalis   ⎪ equal.
   Eucalyptus maidenii   ⎭

Acacia saligna.   Pinus insignis (Fort C.).

The charcoals that gave the highest value, proportional volume of gas produced (per pound of charcoal) multiplied by its calorific value per cubic foot, are :

5. *Eucalyptus sideroxylon* ⎫
   Eucalyptus viminalis   ⎬ nearly
   Eucalyptus resinifera ⎭ equal.

Acacia saligna.   Pinus insignis (Fort C.).

It is of importance to note that *Acacia saligna*, from which such excellent results were obtained, is the common Port Jackson Wattle of the Cape Flats. It is quick-growing, but tender to severe frosts, and yields useful tan bark.

6. The relative mean weights per unit volume (measured as stated), taking that of the Pines as unity, are :

Pines.	Eucalypts.	Acacias.	Natal Anthracite.
1	1·5	1·7	4·8

Cupressus lusitanica gave the lightest charcoal : about three-quarters as heavy as the average of the pine charcoals.

Reference to Earlier Work on this Subject.—The only previous investigational work that, to the knowledge of the present writer, has been done in South Africa on this subject is to be found mentioned in the " Agricultural Journal of the Cape of Good Hope," vol. xxxiii, pp. 710–712, where proximate analyses of charcoal made from Willow, Kaffir Thorn, and Karree are given. Further, a few notes are presented on the relative consumption, by a suction-gas plant, of these three charcoals, but no accurate measurements of consumption per brake horse-power hour appear to have been made. The data in question were given by Mr. F. B. Parkinson, Assoc.R.S.M., F.R.G.S.

For descriptions of the various kinds of kilns and methods of burning,

with the yields of charcoal therefrom, the reader is referred to the Bulletin
of the Forest Department of the Union of South Africa : " Wood Charcoal
and its Manufacture," by J. J. Kotze, B.A., B.Sc., Acting Research Officer.

The author has to thank the staff of the Chemistry Division at this
station for hints in the carrying out of the gas analyses, and also Mr. E.
Silcock, Instructor in the Engineering Division, for help in running the
engine trials.

CHARTS AND COMPARISONS OF THE DISTRIBUTION OF SOUTH AFRICAN ALCYONARIA.

With a Statement of some of the Problems of their Dispersal.

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(With three Charts.)

CONTENTS.

FOREWORD.

The romantic story of the distribution of animals and of their adventures in both space and time cannot properly be understood without a full appreciation of the history of land and water.

On the completion of the identification of all the species of Alcyonaria (with the exception of the Nephthyidae, to be reported on by Dr. W. D. Henderson) collected by the Cape Government trawler between the years 1898–1907, I set myself the following tasks : firstly, to record the distribution of the species on charts, as otherwise the localities taken from the dredging book of the " Pieter Faure " would be to myself and to most others well-nigh meaningless ; secondly, to endeavour to deduce any general points as to the relative occurrence of Alcyonaria and the conditions and reasons therefor at different parts of the South African coast ; and thirdly, to make a com-

parison of the species or genera recorded on the South African coast with
their distribution in other parts of the world's oceans, and if possible to
arrive at the principles under which certain species and genera are present
in certain seas and absent in others.

The first of the tasks, the charting of the species on an Admiralty chart
of the South African coast, was comparatively easy, excepting for the diffi-
culty in finding sufficient space at localities apparently specially favourable
to the life of Alcyonaria.

The second and third tasks are full of difficulties—the greatest of all
being that there is no single species of Alcyonaria of which we know the full
distribution.   It has happened before now in the history of Marine Zoology,
when an attempt has been made to compare two localities from lists
of the animals occurring there, and thus to deduce that a given locality is
like or unlike another area, that the accuracy of the determination of the
species has been denied.

The determination of species, to which some ultra-modern zoologists
apparently attach no importance, becomes one of the utmost significance,
involving as it does, especially in the case of marine sedentary animals,
questions as to the former connections between different oceans and different
lands, for the larval life of such sedentary organisms as Alcyonaria is com-
paratively short, and it is impossible to think of their being distributed,
even by the aid of currents, across wide seas such as from the east side of the
Atlantic to the west side, except through the means of former land connec-
tions.   In the case of certain organisms, such as the Mollusca and Cirripedia,
it is possible to think of the young attaching themselves to seaweeds, etc.,
and so being transported wide distances across the seas ; but in the case of
Alcyonaria this means of transport does not usually, so far as we know,
enter into the question.   In the case of experiments with drift-bottles, it
has been shown that a drift-bottle may be carried from the east side of the
Atlantic to the west side by currents after a journey of thirteen months,
but it is impossible to think of the free-living larvæ of Alcyonaria, with their
short spell of larval life, surviving such an eventful and hazardous journey.
Despite that fact, we have the same species of Alcyonaria living in South
African waters and in the West Indies.

The question, then, of the distribution of marine sedentary animals
living fixed on the ocean floor has significance for problems of Palaeography ;
and it is possible that, if we only had sufficient data as to the occurrence or
distribution of the species of Alcyonaria, then we would be in a position to
solve questions as to former connections between different seas and of earlier
land bridges in existing oceans.

In connection with the distribution of the species of Alcyonaria there is
also bound up the question of their racial history : at which localities do the

primitive forms of a section occur, and in which directions has their distribution extended ?

Gilchrist, in a very interesting paper on " Features of the Marine Fauna of South Africa," * has endeavoured to " point out the key to the whole character of this fauna," and it is undoubtedly the case that the fauna must be influenced to some extent by the warm current on the easterly side and the cold current on the westerly side, but it has sometimes appeared to me that a sufficiently large number of cases was not cited to justify the conclusions.

PART I.

SOME OF THE OUTSTANDING FEATURES OF THE DISTRIBUTION OF SOUTH AFRICAN ALCYONARIA.

Firstly, the following species have been recorded in South African waters and, so far as is known, at no other localities :—

Anthelia capensis, Studer. Discovered off the Cape during the voyage of the " Gazelle "; but as this species has not been rediscovered during the dredgings of the " Pieter Faure," it is possible that there has been some mistake about the locality.

Xenia uniserta, Kükth., and *Heteroxenia capensis*, Hickson, the former in Simon's Bay, False Bay, and the latter also in False Bay.

Alcyonium purpureum, Hickson, a common species, as general at parts of the South African coast as *Alcyonium digitatum* is round European coasts.

Alcyonium valdiviae, Kükth. Collected during the voyage of the " Valdivia " from the southern part of the Agulhas Bank.

Alcyonium Faurii, St. Thomson.

Alcyonium rotiferum, St. Thomson.

Alcyonium (Erythropodium) membranaceum. Collected during the voyage of the " Valdivia."

Alcyonium (Erythropodium) foliatum, St. Thomson.

Metalcyonium novarae, Kükth. " Novara " collection.

Metalcyonium variabile, vars. *molle et durum*, St. Thomson. A very variable species occurring in abundance at various localities from the extreme south to at least as far north as Natal.

Metalcyonium lanceatum, St. Thomson.

It will thus be noticed that the genus Alcyonium, with its sub-genera Metalcyonium and Erythropodium, is well represented in these seas.

Acrophytum claviger, Hickson. The genus, so far as is known, is confined to South African seas.

* Trans. South African Phil. Soc., vol. xv, pt. 4, 1905.

Sarcophytum trochiforme, Hickson. At various parts of Cape Colony, and also Natal.

Anthomastus elegans, Kükth. Collected by the " Valdivia " on the Agulhas Bank, and by the " Pieter Faure " off Natal.

Sinularia (Sclerophytum) unilobata, St. Thomson.

Bellonella Studeri, St. Thomson.

Malacacanthus rufus, St. Thomson.

Suberia capensis, St. Thomson.

Spongioderma Chuni, Kükth.

Anthothela parviflora, St. Thomson.

Melitodes Faurii, St. Thomson. Collected by the " Pieter Faure " both off the coast of Cape Colony and off Natal.

Melitodes grandis, St. Thomson.

Melitodes africana, Kükth. Collected in Simon's Bay.

Mopsella singularis, St. Thomson.

Acabaria valdiviae, Kükth. Collected off the Cape at the depth of 318 metres during the voyage of the " Valdivia."

Wrightella trilineata, St. Thomson. Collected off the coast of Natal.

Wrightella furcata, St. Thomson.

Ceratoisis ramosa, Hickson.

Chelidonisis capensis, Studer.

Muriceides fusca, St. Thomson.

Eunicella rigida, Kükth. Collected by the " Valdivia " and also by the " Pieter Faure."

Euplexaura media, St. Thomson.

Euplexaura capensis, Verr.

Malacogorgia capensis, Hickson, *Trichogorgia capensis*, Hickson (Kükenthal).

Trichogorgia flexilis, Hickson.

Psammogorgia pulchra, St. Thomson.

Stachyodes capensis, St. Thomson.

Stachyodes Gilchristi, St. Thomson.

Thouarella Hicksoni, St. Thomson.

Leptogorgia alba, Verr., var. *natalensis*.

Leptogorgia aurata, St. Thomson.

Leptogorgia abietina, Kükth.

Leptogorgia tenuissima, Kükth.

Leptogorgia africana, St. Thomson.

Leptogorgia pusilla, Kükth.

Lophogorgia Lüthenii, W. and S.

Juncella spiralis, Hickson.

Hicksonella flagellata, Simps.

> *Hicksonella capensis*, Simps.
> *Lophogorgia crista*, Möb.
> *Gorgonia flammea*, E. and S.
> *Gorgonia capensis*, Hickson.
> *Gorgonia albicans*, Köll.
> *Eugorgia Gilchristi*, Hickson.
> *Eugorgia lineata*, St. Thomson.
> *Stenogorgia capensis*, St. Thomson.
> *Scirpearia furcata*, Hickson em. Simpson.
> *Actinoptilum molle*, Kükth.
> { *Virgularia Schultzei*, Kükth.
> { *Virgularia Reinwardti*, Hickson.
> *Umbellula aciculifera*, St. Thomson.
> *Pteroeides isosceles*, St. Thomson.

The main point of interest in this list is that there are over sixty species of Alcyonaria, inclusive of Pennatulacea, which, so far as we know, occur in South African waters and in no other seas: namely, that out of a list of about ninety-eight species recorded from this area, about two-thirds of them are native or endemic, and that the genera Acrophytum, Malacacanthus, Malacogorgia or Trichogorgia, and Actinoptilum are South African. The prevailing South African Alcyonarian fauna is therefore native to this area.

It will be seen from the charts that the following parts of the coast appear to be particularly rich in Alcyonaria :—False Bay ; off Cape St. Blaize ; Algoa Bay ; from Algoa Bay past East London to Cape Morgan ; north-east of Port Natal ; south-east of the Tugela River and St. Lucia Bay.

The fact that a large number of Alcyonarian species are endemic is of importance in connection with the review in a recent paper on the Mollusca of this region, one of the main points of which is that the majority of littoral Mollusca are endemic to the Cape, or at least a much larger number are endemic than has hitherto been supposed.

Kükenthal's views in regard to the Gorgonarian fauna of South Africa are as follows :—

It is composed of very different elements, and is probably the centre of origin of the genera Spongioderma, Lophogorgia, Hicksonella, and Trichogorgia, perhaps also of Eunicella.   Suberia and Chelidonisis are pure Atlantic, and Melitodes, Wrightella, Acabaria, and Euplexaura pure Pacific.   Thouarella and Primnoisis are emigrants from the Antarctic and sub-Antarctic. The genera Muriceides, Acanthogorgia, Leptogorgia, and Scirpearia are widely distributed in the Atlantic and Indo-Pacific seas.   The position of

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Euplexaura capensis, *Psammogorgia pulchra*, and *Eugorgia Gilchristi* is quite uncertain. The area is one of active development as regards the Gorgonarian fauna.

The following species are recorded from the more southern part of the area, chiefly the coast of Cape Colony, which is probably not so much affected by the warm current from the Indian Ocean :—

Clavularia infanta, W. and S.
Clavularia cylindrica, W. and S
Scleranthelia musiva, St.
Anthelia capensis, St.
Xenia uniserta, Kükth.
Heteroxenia capensis, Hickson.
Alcyonium Sollasi, W. and S.
Alcyonium valdiviae, Kükth.
Alcyonium Faurii, St. Thomson.
Alcyonium rotiferum, St. Thomson.
Alcyonium (Erythropodium) membranaceum, Kükth.
Alcyonium (Erythropodium) foliatum, St. Thomson.
Alcyonium (Erythropodium) Wilsoni, St. Thomson.
Metalcyonium novarae, Kükth.
Metalcyonium lanceatum, St. Thomson.
Anthomastus elegans, Kükth.
Anthomastus grandiflorus, Verr.
Bellonella Studeri, St. Thomson.
Malacacanthus rufus, St. Thomson.
Suberia capensis, St. Thomson.
Spongioderma Chuni, Kükth.
Anthothela parviflora, St. Thomson.
Melitodes Esperi, W. and S.
Melitodes nodosa, W. and S.
Melitodes dichotoma, Pall.
Melitodes grandis, St. Thomson.
Melitodes africana, Kükth.
Mopsella singularis, St. Thomson.
Acabaria valdiviae, Kükth.
Wrightella fragilis, St. Thomson.
Wrightella furcata, St. Thomson.
Wrightella coccinea, Gray.
Acanella eburnea, Pourtalès.
Chelidonisis capensis, St.
Acanthogorgia armata, Verr.

Eunicella papillosa, Esper.
Eunicella rigida, Kükth.
Eunicella albicans, Köll.
Euplexaura parciclados, W. and S.
Euplexaura media, St. Thomson.
Euplexaura capensis, Verr.
Trichogorgia (*Malacogorgia*) *capensis*, Hickson (Kükth.).
Hicksonella spiralis, Hickson (Simps.).
Hicksonella flagellata, Simps.
Hicksonella capensis, Simps.
Trichogorgia flexilis, Hickson.
Psammogorgia pulchra, St. Thomson.
Stachyodes capensis, St. Thomson.
Thouarella Hicksoni, St. Thomson.
Villogorgia mauritiensis, Ridley.
Leptogorgia rigida, Verr.
Leptogorgia abietina, Kükth.
Leptogorgia tenuissima, Kükth.
Leptogorgia africana, St. Thomson.
Leptogorgia pusilla, Kükth.
Lophogorgia Lütkenii, W. and S.
Lophogorgia crista, Möb.
Gorgonia flammea, E. and S.
Gorgonia albicans, Köll.
Gorgonia capensis, Hickson.
Gorgonia sp.
Eugorgia Gilchristi, Hickson.
Eugorgia lineata, St. Thomson.
Sinularia unilobata, St. Thomson.
Stenogorgia capensis, St. Thomson.
Virgularia Reinwardti, Hickson.
Anthoptilum grandiflorum, Verr.
Umbellula aciculifera, St. Thomson.
Pteroeides isosceles, St. Thomson.

The predominant feature of the southern area, so far as we know at present, is that, much more than the northern section (coast of Natal), it has an Alcyonarian fauna of its own.

The majority of the new species captured by the " Pieter Faure " were thus from the southern part of the section, though it must be borne in mind that dredgings were made more in the south than in the north ; but, apart from that, the environmental conditions of the southern area more than

those at the northern section are probably more stimulative to changes (see later).

The following species are recorded only from the more northern part of the area (the coast of Natal), which is probably more affected by the warm current from the Indian Ocean :—

Telesto arborea, W. and S.
Alcyonium glomeratum, Hass.
Alcyonium Sarcophytoides, Burchardt.
Metalcyonium molle, Burchardt.
Metalcyonium clavatum, Pfeffer.
Wrightella trilineata, St. Thomson.
Wrightella sp.
Acanella africana, Kükth. (occurring further north than Natal).
Muricella ramosa, Th. and Henderson.
Thouarella (Euthouarella) flabellata, Kükth. (occurring further north than Natal).
Leptogorgia alba, Verr., var. *natalensis,* St. Thomson.
Verrucella bicolor, Nutting.
Cavernularia Lütkenii, Köll.
Funiculina quadrangularis, Pall.
Hicksonella capensis, Simps.

In this list there are few species which do not occur in other seas ; for example, *Muricella ramosa* and *Cavernularia Lütkenii* occur in the Indian Ocean.

The following species are recorded from the northern as well as from the southern area :—

Alcyonium purpureum, Hickson.
Alcyonium pachyclados, Klz.
Metalcyonium variabile, St. Thomson.
Acrophytum claviger, Hickson.
Anthomastus elegans, Kükth.
Sarcophytum trochiforme, Hickson.
Sinularia (Sclerophytum) unilobata, St. Thomson.
Spongioderma verrucosum, Möb.
Melitodes Faurii, St. Thomson.
Wrightella sp.
Stachyodes Gilchristi, St. Thomson.
Hicksonella capensis, Simps.
Scirpearia furcata, Simpson.
Scirpearia flabellum, Simpson.
Actinoptilum molle, Kükth.

The main point of interest which this list brings out is that only about one-sixth of the South African species live both off the coast of Cape Colony and off the coast of Natal. The species occurring in both areas are usually of a variable type, such as Alcyonium, Metalcyonium, Scirpearia, and Actinoptilum.

The South African genera which are best represented as regards the number of species are Alcyonium (including Metalcyonium and Erythropodium), Leptogorgia, and, in a lesser degree, Melitodes, Wrightella, Eunicella, and Euplexaura.

If one passes in review those forms which occur in the southern part of the area, as compared with their distribution in other seas, the genus Clavularia is probably a cosmopolitan one—*Clavularia elongata*, W.S., var. *africana*, may possibly have passed along the South African coast and reached the Azores by means of currents.

Scleranthelia musiva occurs at a South African locality, and is probably partly influenced by the cold Benguela current. It also occurs at the Azores. *Anthelia capensis* was recorded by Studer from the Cape, but species of Anthelia also occur at such widely separated regions as Japan, Scandinavia, the Red Sea, West Indies, and Mauritius.

The distribution of the genera Xenia and Heteroxenia, apart from two doubtful forms, is, on the other hand, one which might be expected from a consideration of the isothermal lines. It has not been recorded from Natal, but one would expect that it would be collected there in the future.

Species of Alcyonium occur both off Cape Colony and off the coast of Natal. This genus is probably a cosmopolitan one, able to live under very different conditions. The occurrence of *Alcyonium Sollasi* off Table Bay, and also off the Strait of Magellan, is interesting; it may be an indication of a former connecting land bridge. In this connection one remembers the occurrence of Cephalodiscus off South Africa and off the Strait of Magellan. As regards the sub-genus Metalcyonium, species occur off the southern limits of South America, South Africa, and off the East Indies.

Alcyonium pachyclados, Klz., is a species which appears to be able to flourish in areas of rather strikingly different temperature. The sub-genus (Erythropodium) occurs off British East Africa near the Gulf of Suez, and off Bouvet Island (Antarctic). The allied *Sympodium punctatum* encrusts Laminarian stalks, and this suggests the possibility of transference on seaweeds.

Sarcophytum is a littoral genus of the warm Pacific and Indian Oceans, but one species occurs off Tristan d'Acunha.

The species of the genus Anthomastus are more usually deep-water; but it is evident that the species of this genus withstand variations of pressure, temperature, and salinity. *Anthomastus grandiflorus*, Verr., recorded from

South Africa, occurs in abundance off the east coast of North America, off Nova Scotia, and off the West Indies.   On the other hand, a link with Japan is found in *Anthomastus granulosus*, Kükth., which is also recorded from two different localities of Cape Colony.

One species of Suberia is recorded from South African seas ; the other species are scattered—namely, off Australia, Patagonia, and Chinese seas. The species seem to occur at localities having a very different temperature, but with a fairly similar salinity ; but there are shallow-water and deep-water species.   It is difficult to account for their distribution, except, perhaps, by an Antarctic and Gondwanaland connection in former geological periods.

A new species of Anthothela has been recorded.   This genus occurs in comparatively deep water ; species occur off the coast of Norway, Newfoundland, and North America.   The occurrence of this species off the south-east coast of Africa is interesting in view of the occurrence of the other species in the North Atlantic.

The distribution of the species of the genus Melitodes is the Indo-Pacific and the Sudanese Red Sea.   A new species of the genus Mopsella has been recorded, the species of which are mainly shallow-water forms, off the Australian coast and the Malay Archipelago.   The genus Acabaria is represented by a new species.   Most of the species occur in fairly deep water, chiefly off the Malay Archipelago, Japanese seas, and the Red Sea.   The recording of three new species of Wrightella is in line with our records of this genus as from the Indo-Pacific Ocean and the Red Sea.

The distribution of the genera Ceratoisis and Acanella presents difficulties ; it is difficult at present to infer the direction and the mode in which the species have spread.   *Acanella eburnea* has been recorded from the south-east of Cape Colony, from the Azores, and from the West Indies.   The distribution is apparently somewhat similar to those of *Clavularia elongata* and *Scleranthelia musiva*, and may probably be to some extent accounted for by the Benguela current running along the west coast of South Africa. *Acanella robusta*, Th. and Hend., is recorded from the Indian Ocean.   The distribution of the genus is predominantly circumtropical, in the coast abyssal, but one species occurs off Patagonia, a second off Japan, and a third off Ireland.   *Villogorgia mauritiensis* was collected off East London, C.C. (" Pieter Faure "), and off the Mauritius by the " Challenger." *Chelidonisis capensis*, Studer (Kükth.), was described by Studer as *Isidella capensis* in 1878, a form collected off South Africa at a depth of 46–92 metres. Another species, *Chelidonisis aurantiaca*, Studer, has been recorded from deep water off the Azores and also off the west coast of Ireland.   As regards Ceratoisis, the Cape species is a member of a widespread genus of the deep sea, occurring far north off Newfoundland, and south in the sub-Antarctic.

It may be almost cosmopolitan. *Acanthogorgia armata*, Verr., has been recorded from South Africa and from the north-east coast of North America. Of the three species of Eunicella recorded from this area, their occurrence helps to strengthen my view that the genus is one which later will be shown to be cosmopolitan.

It is interesting that the study of the distribution of the South African Alcyonaria brings out a similarity which has been pointed out in the case of other groups of animals, namely, a similarity with Japan. Thus amongst the Alcyonaria we find *Euplexaura parciclados*, W. and S., which was collected during the voyage of the " Challenger " off Japan. The genus is Indo-Pacific. Trichogorgia and perhaps Malacogorgia are apparently South African genera. The occurrence of *Psammogorgia pulchra* is puzzling in view of the widely separated localities from which the other species of this genus have been recorded. The record of two new species of Stachyodes, one from the Cape and the other occurring both at the Cape and off Natal, does not seem to point to the probability that temperature has much to do with the limitation of the distribution of the species of this genus. It is probably cosmopolitan. Although some of the members of this genus occur in deep water, such as *Stachyodes gausii*, Kükth., occurring in the Antarctic at a depth of 2,450 metres, yet this is not true of all ; for example, *Stachyodes capensis* occurs off the Cape coast at a depth of 77 fathoms. It would, of course, be of great interest to know about the early life-history of such forms as *Stachyodes gausii.* It is possible that a number of the deep-sea genera of Alcyonaria are viviparous.

The distribution of the Primnoid genus Thouarella suggests a connection with the Antarctic, but species also extend into the Indian Ocean, and as far north as Japan. Species of the large genus Leptogorgia appear to flourish off South Africa ; perhaps the nearest link is with the Indian Ocean, as we have a form, *Leptogorgia ochracea*, occurring off Zanzibar. As regards the genus Lophogorgia, some of the species are rather uncertain ; there is, however, some evidence of the distribution off the south coast of Africa along the west coast of that continent as far north as Cape Verde. *Gorgonea flammea* is a prolific species at the Cape. The genus appears to be mainly Pacific, occurring off the coasts of America from California to Peru. Some of the species from other seas are rather uncertain. The genus Eugorgia, of which two new species have been described from the Cape, has in other seas a similar distribution to that of the preceding genus.

There is a new species of the genus Stenogorgia and some slight evidence of the distribution of the genus from that along the west coast of Africa ; but it is also recorded from widely separated localities in the Atlantic and Pacific, the Arctic Sea, and the Californian Sea. It is frequently, but not always, a deep-water form of the coasts.

When one turns to the Pennatulacea, one finds the Marine Investigations in South Africa have not so far shown the occurrence of many genera or species in this area.

The distribution of the species of the genus Virgularia, of which there are about twenty, is wide; species occurring, for example, far north off Trondhjem, and off Japan.   In regard to the Cape species *Virgularia Schultzei* or *Virgularia Reinwardti* ; if the former, it is more likely an Atlantic species, as specimens occur off British South-West Africa ; if the latter, it is a species of the Indian Ocean and the Pacific, having been recorded from these seas.

In regard to the gigantic Pennatulid, *Anthoptilum grandiflorum*, which forms miniature forests, in the opinion of the author the species is a North and South Atlantic one, an inhabitant of deep water.

A new species of Umbellula has been described.   Umbellula is a genus with over thirty species, occurring in the far north and the far south, the far east and the far west.

A new species of Pteroeides has been described.   The other species of this genus have a fairly continuous coastal distribution on the more southern Asiatic coasts of the Pacific and the Indian Ocean ; species also occur, however, in the Mediterranean and off the Atlantic coasts of North Africa and Southern Europe.   The new species falls into line with the record of a species from the west coast of Zanzibar.

It has been noticed that the Alcyonaria of this area are largely endemic, but indications are not wanting of some approximation to the specific fauna of other regions, such as the east coast of North America, the West Indies, the west coast of Africa, the southern limits of America, the Antarctic, the Indian Ocean, and Japan.

When one passes in review the species occurring in the northern area, one notices the following cases of distribution :—*Telesto arborea*, occurring off the coast of Natal, may be regarded as passing down the coast aided by the warm Mozambique current from Zanzibar, where it has previously been recorded.   *Alcyonium sarcophytoides* occurs in this area and in the Torres Straits, in waters of different temperature, but apparently approximately similar conditions as regards salinity.

The case of *Alcyonium glomeratum*, Hass., is very interesting as showing that in at least some cases Alcyonarian species can live either in comparatively warm or comparatively cold seas, and therefore that one would not expect to find, in all cases, a marked difference between the fauna of the easterly portion as compared with the west coast, the former being washed by the warm current from the Indian Ocean, the latter by a cold Atlantic current —the Benguela current.   The comparison, however, has never been carried out in sufficient detail.   It will be seen later that there is some evidence to show that some species of *Alcyonaria* are eurythermous.   In the mean-

time, we have the occurrence of *Alcyonium glomeratum* in English seas, off the coast of Natal and off New Britain. As regards salinity, the conditions in those three localities are fairly similar.

Metalcyonium molle is recorded from the coast of Natal, its previous record being from Amboina ; the isotherms of these two localities are fairly similar. Another species, namely *M. clavatum*, however, occurs off the coast of Natal, and in much colder water off South Georgia and off Patagonia. Other species, as I have mentioned, occur off Cape Colony. It is possible that there are large gaps in a chain of distribution of the species of Metalcyonium.

Two species of Wrightella are recorded from this area, and this may be correlated with the distribution of this genus further south : it is apparently a genus of the Pacific. *Acanella africana* may be regarded as a species of the Indian Ocean, but it is difficult to infer the trend of distribution of this genus. *Muricella ramosa*, Th. and Hend., may probably be regarded as a species which has extended southwards from the Indian Ocean.

There are twenty-four known species of the genus Thouarella, many of deep water, others from shallow water ; some are sub-Antarctic, others Japanese, others Indian Ocean forms. It has been suggested that Thouarella is an emigrant from the Antarctic or sub-Antarctic. A species of Leptogorgia occurs off the coast of Natal, but this is a large genus, and species are distributed both in the Pacific and the Atlantic. *Verrucella bicolor*, Nutting, is recorded from the Natal coasts and from the Hawaiian Islands. *Cavernularia Lütkenii* is an Indian Ocean form which has wandered southwards, and Funiculina occurs widely, including the Indian Ocean. Thus there are species common to this area and to the Indian Ocean, English Channel, New Britain, South Georgia, Patagonia, Torres Straits, Amboina, and Hawaiian Islands.

Of the species occurring both in the southern and northern section of the area there are comparatively few.

Two species of Alcyonium, namely *A. purpureum* and *A. pachyclados*, may be regarded as adaptable species of an adaptable genus. Similarly, a species which shows a great range of variability, and therefore a great power of adaptation, is *Metalcyonium variabile*, in two varieties. This occurs in great abundance, and the two varieties may occur in the same haul of the dredge. Species of Anthomastus also occur both in the northern and southern areas.

Acrophytum claviger is an extremely well-protected form, living in shallow water, which is probably exposed to the heavy surf so characteristic of these seas. Another form of the south and the Azores similarly protected is *Scleranthelia musiva*. From the distribution of Sarcophytum it is difficult to deduce any contrast as regards influence of temperature, as, while most

are tropical littoral of the Indo-Pacific, yet one is said to occur off Tristan d'Acunha, and thus in conditions of different temperature and salinity.

The occurrence of a new species of Sinularia, on the other hand, seems to support the view that this genus is mainly an inhabitant of the warmer seas. *S. brassicae* was recorded from British East Africa. The genus Spongioderma is probably endemic to South Africa. The genus Melitodes may probably be regarded as Pacific.

From the distribution of the genus Stachyodes we would infer that it is one which can live in different conditions, and the same may be said of *Scirpearia furcata* and *Scirpearia flagellum*.

A characteristic, prolific, and very variable species occurring both in the north and south is *Actinoptilum molle*, Kükth.

The question might be asked, Are the species recorded from the more northern part (Natal) specially indicative of an approach to the Indian Ocean or Pacific Ocean, and those of the southern part less so and more nearly an approach to the Atlantic?

If one passes in review the species occurring only in the northern part, one has *Telesto arborea*, which also occurs off Zanzibar; *Alcyonium sarcophytoides*, in the Torres Straits; *Metalcyonium molle* also occurs in the Pacific, but *Metalcyonium clavatum* in the South Atlantic; Wrightella is more predominantly a genus of the Pacific, and also occurs off the Cape Colony as well as off Natal. Species of Acanella occur in the North and South Atlantic, as well as in the Indian and Pacific Oceans. Muricella is a genus of the Pacific Ocean, Indian Ocean, and Red Sea. The species of Leptogorgia are distributed in the Atlantic, Pacific, and Indian Oceans. The distribution of the genus Verrucella is mainly in parts of the Pacific Ocean, Indian Ocean, and Red Sea. *Cavernularia Lütkenii* is apparently an Indian Ocean form which has passed south. *Funiculina quadrangularis* is not predominantly an Indian Ocean or Pacific Ocean form, but is apparently independent of divergences in temperature and pressure.

We are able to say that out of a total of sixteen species, about a third of these show approximation with those of the Pacific and Indian Ocean, as compared with a proportion of a seventh in the southern area. I would, however, infer that there is also an Atlantic strain, as is also the case with the southern area, which is probably due to the existence of a former land bridge between South America, South Africa, and India (see p. 62). There is, however, apparently no sharp line to be drawn between the southern and northern sections, excepting in so far as the former has more predominantly an Alcyonarian fauna of its own.

In regard to Alcyonaria as a whole, I would ask the question if the evidence in certain cases does not contradict the view that they are all influenced in their distribution by temperature. The prevalent view is

that the south-west and west coast, being influenced by the cold Benguela current, has naturally a different fauna from that of the East coast, affected by the warm Mozambique current. While holding that there is justification for this view, I regard certain genera as adaptable, as being able to live and flourish in seas of different temperature, etc. ; other genera as non-adaptable and therefore restricted in their range of distribution.

In this connection it is also possible that the larval life of the species of certain genera is longer than in others, but for this supposition we have no available facts.

On the west coast the commonest littoral Pennatulid is probably *Cavernularia elegans* (Herklots), Kölliker ; but this species also occurs in the Indian Ocean and off Japan. On the eastern side *Cavernularia Lütkenii* occurs off the Indian Ocean and has penetrated as far south as the coast of Natal. *Actionoptilum molle*, Kükth., is one of the most common and abundant species on the east coast. *Veretillum cynomorium* and *Pavonia africana* occur on the west coast, but have not been recorded from the east ; the former of these, however, occurs in the Mediterranean and Bay of Biscay. *Veretillum cynomorium* has been regarded by Balss as a northern sub-tropical form which has migrated north and thence into the Mediterranean and south again to the west coast of Africa. *Virgularia Schultzei*, Kükth., has been interpreted by some as an Antarctic species which has passed to the Cape and thence northwards along the west coast of Africa, occurring, for example, off Luderitz Bay.

The question, therefore, remains in need of further investigation and scrutiny. I am unfortunately unable through lack of data to compare in detail the Alcyonaria of the west and south coasts of Africa.

One has, however, a paper by Cohn on the Alcyonacea of Madagascar, which shows striking difference from our area and yet resemblances in genera. The following similar genera occur in both : Sarcophytum, Sinularia, Alcyonium, Xenia, and Clavularia. Two rather uncertain genera occur at this higher latitude, not recorded from the Cape, namely Lobophytum and Sympodium. The following species have been recorded from both areas :—*Alcyonium pachyclados*, which is probably to be regarded as a prevalent species of the Indian and Pacific Oceans ; *Xenia florida* occurs off Cape St. Blaize and off Madagascar. Kükenthal gives short lists of the Gorgonarian species from the west coast of Africa (from the Strait of Gibraltar to north of the Cape) ; secondly, of the south coast of Africa to the northern border of Natal ; and thirdly, of the east coast of Africa to Bab-el-Mandeb, including Zanzibar.

The point of these lists is that the species are not similar except in the case of *Lophogorgia crista*, which is recorded both from the west and south coasts.

Kükenthal does not believe in a similarity between species of the Indo-Pacific and Mediterranean, as of the Gorgonarian fauna occurring in the Red Sea no species are known in the Mediterranean. He believes that the Mediterranean fauna receives additions from the Atlantic.

COMPARISON WITH MOLLUSCAN FAUNA.

It is of great interest and importance to compare the distribution of the Alcyonaria of the Union of South Africa with the distribution of the Mollusca of that region. A very interesting paper by J. R. le B. Tomlin on " Some Remarks on the Cape Marine Province " has recently been published in the Journal of Conchology, Jan. 1922.

The points contained in this paper are the following :—

Firstly, a survey of the currents on these coasts.

Secondly, the presence on the eastern side of a " fairly plentiful admixture of well-known tropical shells from the Indian Ocean down the coasts of Zululand and Natal. Probably Durban is pretty nearly the farthest limits of these invaders."

Thirdly, that " the trend of the Atlantic currents should make one chary in admitting palaearctic species to the South African list."

Fourthly, Sowerby's list of thirty-four European species occurring off the South African coast is reduced to three. These three species are apparently common to Britain, the Mediterranean, and South Africa.

Fifthly, that the Cape fauna is very largely composed of endemic species, the Cape list " is still encumbered with aliens of whom the great majority will have eventually to be recommended for deportation."

Sixthly, that there are probably a number of special genera.

Seventhly, " Delagoa Bay seems to have preponderatingly a mixture of Indian Ocean Mollusca, and it is probably just south of this that the endemic Cape element becomes dominant."

The limit of the Cape element on the west coast is probably at the mouth of the Cunene River.

Eighthly, data are not so good for the western coast, but from what was German South-West Africa one has about thirty species which are characteristic Cape shells. At Walfish Bay a species occurs which is also recorded from the Gulf of Guinea and the West Indies, thus showing West African influence.

Ninthly, further north, at Great Fish Bay, the West African element becomes more predominant, though a species occurs which is also recorded from the Cape, in the Agulhas current. Passing northwards to Mossamedes, a list of species is recorded which are also ascribed to the Cape. One species is interesting as occurring also at Walfish Bay and Natal. Some of the

species the author expunges, but there still remain a few Cape species whose range extends to Mossamedes or even farther north, no doubt by the agency of the Benguela current. Other species he regards as West African littoral, as species which have worked their way southwards along the coast. The Molluscan fauna of Mossamedes is mainly West African, though a few skirmishers reach it from the Cape.

The interesting point is that the distribution of this Molluscan fauna thus shows fairly general agreement with the results worked out for the Alcyonaria of the Union of South Africa. Tomlin appears on the whole to lay stress on the *endemic* character of the Cape Fauna, while Gilchrist apparently emphasises its *cosmopolitan* character.

ENVIRONMENTAL FACTORS IN DISTRIBUTION.

It would be interesting if we knew the detailed conditions in which Alcyonarian species live, to show how their form is adapted to their environment in different cases, but many data necessary for such a comparison are wanting.

One of the prevailing conditions on the South African coast is a low tide range, with a strong surf, and this may probably be correlated with the occurrence of low-growing compressed forms such as *Alcyonium purpureum*, in other cases, such as that of *Scleranthelia musiva*, one finds also a very massive protection of spicules. Among the Pennatulids a prevailing form is Actinoptilum, a radial form without an axis, for the latter there is no advantage in an animal living in quickly moving water. The animal is protected by the water streaming in on all sides and by the great and rapid retractibility ; in deeper water one has Funiculina with an elastic axis. The forms of the upper littoral should be contrasted with those of intermediate still water, and the latter with those of the deep sea.

As regards the influence of temperature, some genera such as Umbellula may be regarded as cold water, and others such as Pteroeides as warm water, but there is surely some evidence that the species of some genera are adaptable and others are not ; in other words, some are eurythermous and others stenothermous. It is evident that there is no sharp separation in nature between cold- and warm-water seas.

Other four factors about which we know little enter into the question : firstly, the length of the larval life ; how short or how long this is in individual genera we do not know, but probably the duration is only about two or three weeks. Thus the possibility of the far distribution of the species is not great ; but we do not know the conditions of larval life in the case of the deep-sea forms. Secondly, as regards pressure at different depths, one finds the same species occurring at very different levels.

Thirdly, we do not know sufficient about the salinity conditions ; but there is some evidence in this paper of certain species occurring under similar conditions so far as we know them. Fourthly, the nature of the sub-stratum in all probability has an influence as to whether the larvæ find suitable grounds for settling or the reverse. In this connection the sub-stratum of green mud on parts of the south and west coast of Africa may have something to do with the difference of the Alcyonarian fauna there as compared with that of the east coast.

Geological Factors in Distribution.

Former Lands and Seas.—Reference has already been made to the shortness of the duration of the larval life, and thus to the hindrance to the distribution of the species across wide seas. In order to account for cases of dispersal, one has to remember that the distribution of land and sea was not always as it is to-day. Some of the former land and sea connections of the past, which may aid in solving the problem of the distribution of Alcyonaria, are as follows :—

The presence of a former Antarctic continent extending west and east, forming a land bridge from South America to Australia and making it possible for Alcyonaria to migrate along the coast line.

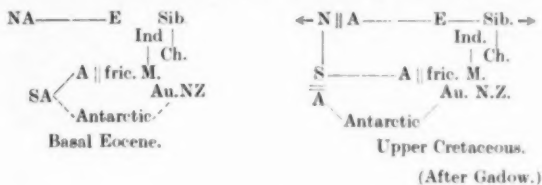An early land connection between Northern Europe and Northern America.

A land mass extending from the north coast of Africa to the West Indies —the lost Atlantis or " Archelenis." This might explain the occurrence of similar forms in the Mediterranean and the Antilles. To the south, " Gondwanaland " proper—namely this former connection between South America, Africa, Madagascar, and India—might explain resemblances between the species occurring in the Atlantic coasts of South America, South Africa, and the Indo-Pacific. It is possible that species migrated along the south coast of Gondwanaland from South America eastwards, and also that they might pass along the coast of the Patagonian-Antarctic-Australian bridge.*

The Straits of Central America—a shallow sea possibly enabling migra-tion to take place from the Pacific to the Atlantic.

A second connection between the Indo-Pacific and the Atlantic, namely a connecting sea between the Indo-Pacific and Atlantic Oceans, over Asia Minor and Southern Europe.

* In this connection, however, Tate Regan's conclusions are : " Neither the fresh-water fishes, nor the marine fishes, whether Antarctic or South Temperate, support the theory that Antarctica has connected Australia with South America in Tertiary Times " (Fishes, Terra Nova Expedition).

The probable connections may be represented roughly by the accompanying schemes, in which straight lines indicate continuity of land, dotted lines show transient connections, parallel lines indicate separation by the sea, and the position of the present continents are expressed by their initials.

<pre>
NA————E   Sib.   ←N ‖ A————E——Sib. →
           Ind | Ind. |
           | Ch. | Ch.
       A ‖ fric. M.   S————A ‖ fric. M.
SA<   Au.NZ   =
                             A   Au. N.Z.
   ·Antarctic·   ·Antarctic·
Basal Eocene.   Upper Cretaceous.
</pre>

(After Gadow.)

INFLUENCE OF OCEANIC CURRENTS.

A very interesting point, but one of extreme difficulty, is the relationship between the distribution of Alcyonaria and oceanic currents. It seems undoubtedly the case that their distribution must be aided by favourable currents, but to make any general statement at present as to the individual species is rather precipitate until we are able to decide whether those are eurythermous or stenothermous. In other words, while in certain cases the distribution of the species might be aided by currents, in other cases, such as the meeting with a cold current, the dispersal might be hindered.

With the permission of the publishers, I reproduce a chart of Ocean currents from the " Science of the Sea," issued by the Challenger Society. In regard to the South African area, the warm Mozambique, Natal, and Agulhas currents, passing down the east coast, is barred south of the Cape by the Antarctic Drift to an extent which produces a recurving of the Agulhas from a south-west to easterly direction ; thus at this point there is a constant conflict between these two bodies of water and one has the cold Benguela current passing up the west coast of Africa.* The evidence is not great, but it appears to me that there are indications that some forms from the east coast can pass round the Cape and then northwards along the west coast of Africa ; but on the other hand there are species which do not migrate in the direction indicated.

In the group of fishes, the Snoek, *Thyrsites atun,* occurs off the Chilian coast of South America, at Tristan d'Acunha, on the west coast of Africa, and on the west coast of Australia, that is, off those coasts on which the Antarctic drift impinges. It would be interesting if we found a parallel case among the Alcyonaria, but we have to remember the shortness of the laval life in this connection.

* The richness of the fish fauna on the Agulhas Bank is perhaps due to this locality being one where the currents meet (see " Progression of Life in the Sea," Allen, E. J., Brit. Association Reports, 1922).

On the coast of America, influenced also by similar currents, one has again evidence of species which occur both in the cold and warm water zones, while other species, on the contrary, seem confined to special areas ; but in both cases one requires further evidence. Similar species occur off California and Japan, and possibly this is to be explained by the Kuro-Shiwo current.

It is, however, amply evident that the question of currents has to be taken into consideration in attempting to understand the distribution of Alcyonaria. One concludes that there are many gaps in the actual distribution of species as compared with their records. One is confronted with such difficulties as the isolated occurrences of a species in the English Channel, off Amboina, and off the coast of Natal. A possible dispersal seems to be from Amboina by the South Equatorial drift to the Red Sea, thence into the Mediterranean and European coasts. An identical or closely allied species, *Alcyonium compressum*, Stud., was collected in the Gulf of Gascony. The improbability of a dispersal from the Indian Ocean *via* the Red sea into the Mediterranean, has, however, been pointed out for the Gorgonaria by Kükenthal. As opposed to the distribution of *A. glomeratum*, one has the case of the species of the warm-water genus Pteroeides, whose distribution forms an almost continuous band mainly in the Indo-Pacific Ocean. A resemblance between the Pennatulids on the coasts of Greenland and North America has been explained by the carrying of the larvæ by the Gulf Stream. The identity of species off the Antilles and off Bermuda might also be explained by the Antilles current.

ENDEMIC AND COSMOPOLITAN CHARACTERS.

From the identity or close similarity of species we are led to infer that the Union of South Africa, besides possessing an endemic Alcyonarian fauna of its own, also shows some similarity, differing in degree, with the Alcyonaria of the following : the Azores, Tristan d'Acunha, the West Indies, the west coast of Africa, South America (Patagonia), the Antarctic (Bouvet Island), the Indian Ocean, the Pacific Islands, the Mediterranean, the English Channel, the East Indies and Melanesia, Japan, both coasts of America, and the north coast of Australia. These resemblances cannot at present be fully understood owing to gaps in our knowledge of the occurrence of species, but partial explanations can at least be sought for in a study of the oceanic currents and the configuration of the world in geological times, for the study of animal geography is the story of the romance of land and sea.
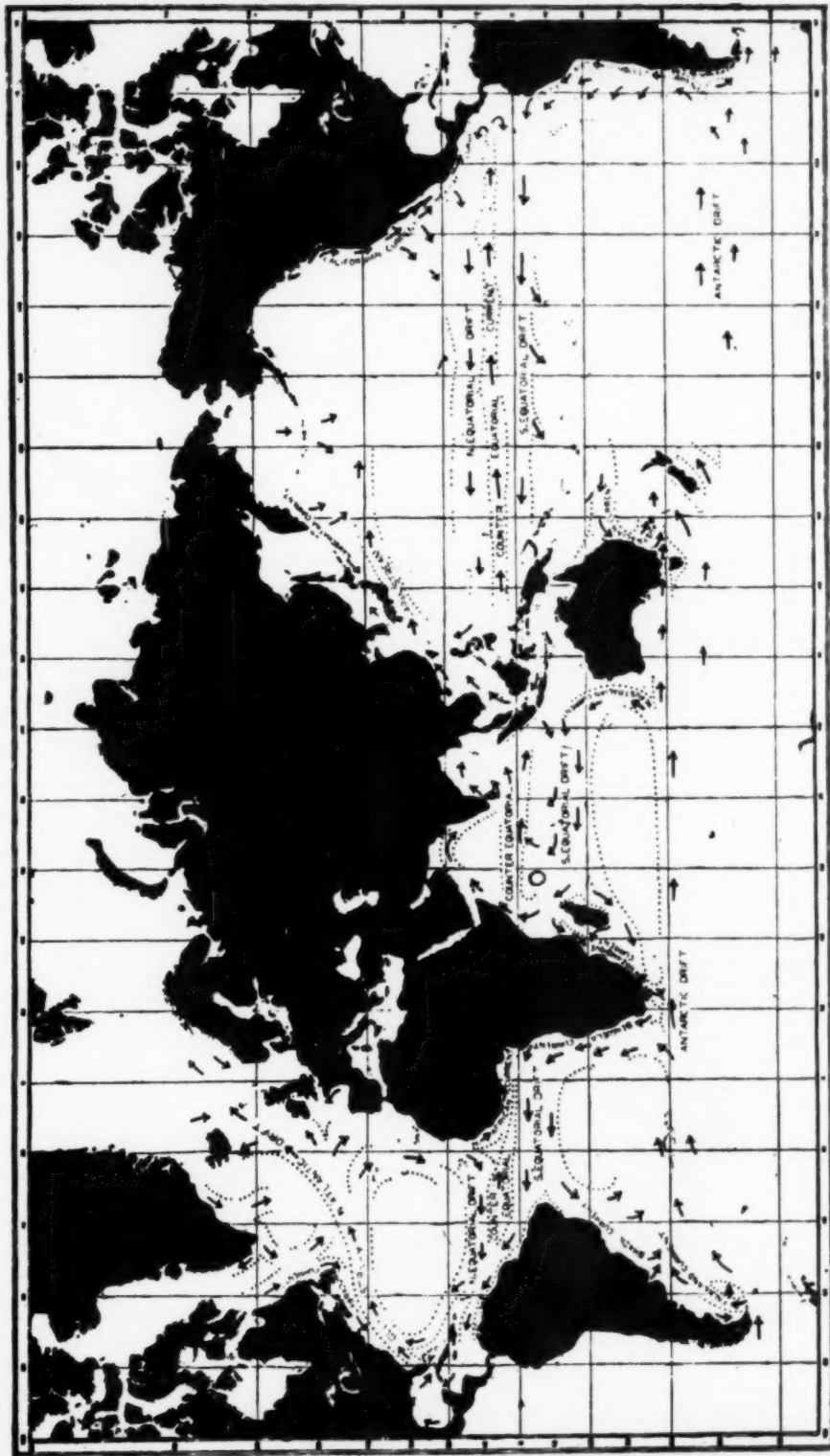
Chart III.

OCEAN CURRENTS.

Based on Admiralty Chart 3,528.   The arrows indicate the direction, the dotted lines the approximate boundaries, of the main surface currents.

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PART II.

Key to Distribution as shown in the Charts.

This part of the paper gives the rough distribution of the Alcyonaria of the Union of South Africa, as shown in the Charts. The detailed localities of their occurrence as marked in the Charts are not, however, taken from these rough indications, but from the exact bearings, as given in my previous papers (see Bibliography). The records of their occurrence in other regions are also noted.

ALCYONACEA.

Family Cornulariidae.

Genus clavularia.

The distribution of this very variable genus, of which over sixty species have been recorded, is very extensive, species occurring in all the great oceans, in the Arctic and Antarctic, and similarly in the East and West. As previously stated in a former paper, I do not agree with Kükenthal in regarding the genus Clavularia as exclusively deep-water, and thus to be contrasted with the nearly related Anthelia as a shallow-water form. The genus has been spoken of by some authorities as in a " state of flux."

Clavularia elongata, W. and S., var. *africana*. In shallow water, south-east of Cape Infanta. This species was first collected during the voyage of the " Challenger " off the Azores. In the course of this review of distribution it will be noticed that other species of Alcyonaria occur off South Africa and off the Azores, such as *Scleranthelia musiva*.

Clavularia cylindrica, W. and S., off Seal Island, False Bay, in shallow water. This species was first collected during the voyage of the " Challenger " off Nightingale Island, Tristan d'Acunha, in comparatively shallow water. Its distribution may possibly show the influence of the Antarctic drift.

Scleranthelia musiva, Studer. In shallow water, south-east of Cape Henderson, Cape Colony. It is interesting to compare this record with the occurrence of the same species as collected during the voyage of the " Gazelle " in a very different locality, both as regards temperature and salinity, namely the Atlantic at 15° 52′ N. lat. ; 23° 8′ W. long., at a depth of 115 fathoms (not far from the Azores). (In Studer's paper (Gazelle), the specific name is written *musiva*, but in the Challenger Report as *musica*.)

Genus anthelia.

Kükenthal has transferred a number of species of Clavularia to the genus Anthelia, but excluding these until the point is more definitely

5

ascertained, we have *Anthelia lineata*, Simpson (1906), from Hong Kong ; *Anthelia capensis*, collected at the Cape of Good Hope by Studer ; *Anthelia japonica*, Kükth., from Japanese seas ; *Anthelia borealis*, Kor. and Dan. ; and *Anthelia fallax*, Broch., from Trondjemsfjorides, and some poorly described or doubtful species, such as *Anthelia strumosa*, Ehren., and *Anthelia purpurascens*, Ehr., from the Red Sea ; *Anthelia filippi* from Guadeloupe, West Indies ; and *Anthelia dujardinii* from the Isle of France, Mauritius. It is curious that, although such extensive dredging was subsequently done by the " Pieter Faure " at the Cape, *Anthelia capensis* has not again been recorded.

There appears little resemblance in the localities quoted as regards temperature and salinity conditions.

Family TELESTIDAE.

The genus Telesto occurs in the warmer areas of the Atlantic, but most frequently in the Indo-Pacific, and the species are usually from the lesser depths. *Telesto arborea*, W. and S., in shallow water, south-east of Port Shepstone, Natal. This species has also been recorded from Zanzibar, the Arafura Sea, off Amboina, and Sydney.

Family XENIIDAE.

Genera XENIA and HETEROXENIA.

The chief area of distribution of the species of Xenia is apparently the warmer seas of the Indian Ocean ; many species are inhabitants of the coral reefs. Species of Xenia occur off the coast of Mozambique, off Madagascar, off East Africa, off Japan, and a number of species from the eastern part of the Indo-Pacific, such as the Malay Archipelago and Polynesia. A few species occur in the Red Sea. Three species, *Xenia uniserta*, *Xenia florida*, and *Heteroxenia capensis*, occur off South Africa. Kükenthal cites the interesting case of two nearly related species, *Xenia antarctica*, Kükth., occurring off Bouvet Island in Antarctica, and *Xenia (Ceratocaulon) Wandeli*, Jungersen, occurring in the North Atlantic off Iceland, with no species, so far as known, existing at intermediate localities. In my opinion *Xenia antarctica* and *Xenia (Ceratocaulon) Wandeli* are species of Ceratocaulon, and distinct from the true species of Xenia. The species of Xenia are mostly inhabitants of warmer seas in comparatively shallow water and often associated with corals, but are not necessarily inhabitants of the coral reefs, though that is frequently the case. *Xenia antarctica* and *Xenia (Ceratocaulon) Wandeli* are deep-water forms. Of the remaining related species, *Heteroxenia capensis*, Hickson, *Heteroxenia Elizabethae* (Australia and

Zanzibar), and *Xenia uniserta*, Kükth. (S. Africa), may or may not be associated with corals or coral reefs. For example, *H. Elizabethae* occurs in the Great Barrier Reef, but also in mud on the beach near Zanzibar Town (Kiungani).

Xenia uniserta, Kükth., from Simon's Bay, South Africa, is, according to Küthenthal, closely allied to *Heteroxenia capensis*, Hickson. It is not here my intention to enter into the much discussed question as to the occurrence or non-occurrence of siphonozooids, and as to whether Xenia and Heteroxenia should or should not be included in the same genus. To the writings of Kölliker, May, Bourne, Ashworth, Hickson, Kükenthal, and other authors, reference may be made. *Heteroxenia Elizabethae*, Köll., was recorded from off Port Denison (Kölliker) and off Zanzibar (Bourne, Ashworth, Thomson and Henderson) ; *Heteroxenia capensis* from False Bay at a depth of 20 fathoms. I have recorded *Xenia florida* (Lesson) from off Cape St. Blaize in shallow water (110 fathoms) on a substratum of broken shells, rocks, and corals. This species has also been recorded from off New Zealand and New Hanover, off Port Denison, off the north coast of the Kei Islands, off the Fiji Islands, off Tamatave, Madagascar, and off Ternate.

Kükenthal regards *Xenia uniserta* and *Heteroxenia capensis* from South African seas as being more or less primitive forms, and regards these seas as the area of occurrence of primitive Xenia ; but one may express doubts about this view in reference to some of the characters which he selects as primitive. Kükenthal reads the distribution of Xenia as follows : The two species, *Xenia antarctica*, Kükth., and *Xenia (Ceratocaulon) Wandeli*, Jungersen, are either Xenias or belong to the sub-genus Ceratocaulon. He supposes that the original centre of the genus Xenia is the sub-Antarctic area, south of Africa, from which they were further distributed in the Indian Ocean, that probably further species of Xenia will be discovered in the Atlantic, intermediate between Iceland in the north and Bouvet Island in the south. This supposed distribution does not satisfy one completely ; it appears more probable, from what is known of the structure of Xenia, from the distribution of the species, that the original centre was the warmer seas of the Indo-Pacific Ocean, that some have passed northwards into the Red Sea, and others have passed southwards to South African waters, carried by the Mozambique and other currents.

The distribution of the nearly related genera Xenia and Heteroxenia in the Indo-Pacific and South African seas is that which one would expect from a consideration of the isothermal lines of the surface water in February and August and from a consideration of the currents. The two remaining known species, *X. antarctica* and *X. Wandeli* (*Ceratocaulon*), occur far to the north and south of similar isothermal lines, and this similarity has to be correlated with their occurrence in deep water.

Family ALCYONIIDAE.

Genus ALCYONIUM.

From the general distribution of this genus, in the far north and in the far south, in comparatively cold and warm seas, one is led to infer that it is one of great adaptability to different conditions. *Alcyonium purpureum* and others may be endemic to the Cape, but on the other hand, *Alcyonium Sollasi* occurs off Table Bay and near the Strait of Magellan, and *Alcyonium glomeratum* is recorded from the English Channel, from off Natal, and from New Britain. The distribution of the species of Alcyonium, as of many other genera, is known only in part, and any generalisations made at present would probably only be shattered in the future, but the genus has a very wide distribution, species occurring in the Arctic and Antarctic.

Alcyonium purpureum, Hickson. A very common form on the shore and in shallow water, apparently both in Cape Colony and Natal. This species has not so far been recorded from other seas.—*Alcyonium Sollasi*, W. and S., near the mouth of Table Bay at a depth of 22 fathoms. This species was first recorded at the entrance to the Strait of Magellan at a depth of 55 fathoms.—*Alcyonium valdiviae*, Kükth. (" Valdivia " Collection), from the southern part of the Agulhas Bank (35° 21′ S.Br. and 20° 56′ 2″ O.L.) at a depth of 100 metres.—*Alcyonium pachyclados*, Kl., a common shallow-water form, at a depth of about 10–45 fathoms, off many parts of Cape Colony. This species has been recorded from Albay Luzon, the Red Sea, Zanzibar, the Maldives, New Britain, and other localities in the Indian and Pacific Ocean.—*Alcyonium Faurii*, St. Thomson, apparently a rather rare form, occurring at a depth of 36 fathoms, south-south-east of Cape St. Blaize, Cape Colony; not recorded from other areas.—*Alcyonium rotiferum*, St. Thomson, in shallow water at a depth of 20–30 fathoms, off the coast between Port Alfred and East London, Cape Colony; not recorded from other seas.—*Alcyonium glomeratum*, Hassall, off Durban, Natal, depth 85 fathoms; nature of bottom, sand and shells. This species has been recorded from such widely separated localities as the English Channel and Talile Bay, New Britain (Hickson).

Alcyonium (Erythropodium) membranaceum, Kükth., at a depth of 20–30 fathoms in Mossel Bay and Algoa Bay. This species was first collected during the voyage of the " Valdivia," at St. Francis Bay at a depth of 100 metres. It has not so far been recorded from other seas.—*Alcyonium sarcophytoides*, Burchardt; off Durnford Bay, Natal, at a depth of 20–30 fathoms. This species was previously recorded from off Thursday Island, Torres Straits.—*Alcyonium (Erythropodium) reptans*, Kükth. off O'Neil Peak at a depth of 90 fathoms. This species was first collected during the

voyage of the " Valdivia " on the east side of the Bouvet Island (Antarctic) at a depth of 457 metres.—*Alcyonium (Erythropodium) foliatum*, St. Thomson, off Cape Morgan, at a depth of 20–30 fathoms, first record. *Alcyonium (Erythropodium) Wilsoni*, St. Thomson, off the coast near Knysna, Cape Colony, at a depth of 30–40 fathoms ; not recorded from other seas. — One species, i.e. *Alcyonium (Erythropodium) reptans* is recorded off Bouvet Island (Antarctic), and it is possible that this occurrence may be accounted for by a former partial land connection in geological times with the Antarctic (see p. 46).

Sub-genus METALCYONIUM.

The species of the genus or sub-genus Metalcyonium are recorded from South Georgia, southern part of the Indian Ocean, Torres Straits, Amboina, Patagonia, Japan, and south and east coasts of South Africa. The distribution of the genus may point not so much to distribution by currents, but to one or more former connections, in geological times (see later).

Metalcyonium novaræ, Kükth. (" Novara " Collection). False Bay, Cape Colony, at a depth of 10–25 fathoms.—*Metalcyonium variabile*, vars. *molle et durum*, St. Thomson—*Alcyonium antarcticum*, Hickson. It will be seen from the chart that this species was collected at a number of localities ranging from Vasco da Gama to Natal and at various depths. The two varieties may occur in the same haul of the dredge. Its great variability is commented on in my papers. It has resemblances to an antarctic form (*A. antarcticum*) and to a South American form (*M. patagonicum*).

Metalcyonium molle, Burchardt, off Umhloti River mouth, Natal. Previously collected in Austro-Malayan seas.—*Metalcyonium clavatum*, Pfeffer. Off the coast of Natal, at a depth of 36–40 fathoms. This species has also been recorded from South Georgia, Patagonia, Amboina, and Japan. —*Metalcyonium lanceatum*, St. Thomson. Off Great Fish Point lighthouse at a depth of 22 fathoms.

Genus ACROPHYTUM.

Acrophytum claviger, Hickson.

Metalcyonium natalense, St. Thomson. This genus, so far as is known at present, is confined to South African seas. The following localities may be noted : Algoa Bay, Cape Colony, 20 fathoms : off Cape Morgan, Cape Colony, 25–40 fathoms (current) ; off Port Shepstone, Natal, 35–45 fathoms ; off Umhloti River mouth, Natal, 30–40 fathoms ; off Durnford Point, Natal, 25–80 fathoms ; off Umzimaylo River mouth, Natal, 30–49 fathoms.

Genus SARCOPHYTUM.

The distribution of this genus is mainly the tropical littoral of the Indo-Pacific Ocean ; but a species is recorded from the South Atlantic off Tristan da Cunha.   *Sarcophytum trochiforme*, Hickson ;   *Anthomastus trochiforme*, Kükth.   Among other localities it was collected at the following : off Cape Henderson, Cape Colony, at a depth of about 48 fathoms ; off Umkomass River mouth, Natal, at a depth of 40 fathoms ; off Umhloti River mouth, Natal, at a depth of 30–40 fathoms ; off Tugela River mouth, Natal, at a depth of 30 fathoms.   The probability is that further dredging will show this genus to be much more widely distributed than has been supposed.

Genus ANTHOMASTUS.

The genus Anthomastus has been described as being well-nigh cosmopolitan ; it has been recorded from widely separated localities, in the Atlantic, Pacific, and Indian Oceans, from the far north off Trondjem and from the far south off Bouvet Island, and similarly from the east and west.   It is more frequently a deep-water rather than a shallow-water form, though *Anthomastus granulosus* occurs at a depth of 32 fathoms off East London, Cape Colony, and at a depth of 20 metres at Tokio Bay, Japan.—*Anthomastus elegans*, Kükth., off Umhloti River mouth at a depth of 40 fathoms.   This species was first collected during the voyage of the " Valdivia " at the southern part of the Agulhas Bank (lat. 35° 19′ S. ; long. 20° 12′ E.)—*Anthomastus grandiflorus*, Verr., in deeper water (141 fathoms) far south of Chelsea Point, Algoa Bay.

Genus SINULARIA (SCLEROPHYTUM).

The distribution of this genus is rather uncertain owing to difficulties with doubtful synonyms.   It is apparently mainly an inhabitant of the warmer seas, chiefly the Indo-Pacific Ocean.   Species are recorded from Zanzibar and Madagascar.

Sinularia densum, recorded from Funafuti (East Indies), from the Chinese seas, from British New Guinea, the Maldives, and Ceylon, is one of the most widely distributed species.   It is mainly a shallow-water genus.—*Sinularia* (*Sclerophytum*) *unilobata*, St. Thomson, is recorded from a depth of 45 fathoms (currents) south-east of Cape Morgan, Kaffirland ; off Red Hill, Kaffirland ; off Umhlanga River mouth, Natal, and off Buffalo River, near East London, Cape Colony.

Genus BELLONELLA.

Species of this genus have been recorded from the Bellona Reefs, Australia, from off the coast of Portugal, the Gulf of Guinea, the Azores,

the Gulf of Naples, Gulf of Gascony, the Philippines, Japanese and Arctic seas. It is apparently a genus which can withstand a great range of conditions as regards temperature and salinity.

Bellonella Studeri, St. Thomson. Off Red Hill, Kaffirland, in shallow water.—*Sinularia unilobata* was also collected from this locality.—*Bellonella rubra*, Brundin. The exact South African locality of this specimen was lost owing to the obliteration of the label. It has also been recorded from Japanese seas.

Genus MALACACANTHUS.

Malacacanthus rufus, St. Thomson. This new genus and species without spicules was collected off the Cape Peninsula in very shallow water.

In connection with Alcyonacea, one may here notice the interesting recent record of a new species, *Acrossota liposclera*, Bourne, apparently a primitive Cornularian which has simple non-pinnate tentacles, thus differing from all other known Alcyonaria. Its record is from the d'Entrecasteaux group of islands, British New Guinea.

GORGONACEA.

Family BRIAREIDAE.

Genus SUBERIA.

Species of this genus are recorded from Port Jackson, Australia, north of New Zealand, in the Atlantic, off Monte Video and the east coast of Patagonia, off Obi Major, Chinese Seas, and off the Dutch East Indies. The species of this genus usually occur in shallow water, but *Suberia macrocalyx* is recorded at a depth of 1165–1264 metres off the Dutch East Indies.

The new species *Suberia capensis* collected by the " Pieter Faure " is from shallow water (about 50 fathoms, current), south-east of Cape Henderson, East London.

Genus SPONGIODERMA.

This genus may be endemic to South African seas. With the exception of *Solanderia*, sp. Ridley, recorded from off Thursday Island, Torres Straits, and which may not be identical with Spongioderma, species have only been recorded from these seas.—*Spongioderma verrucosum*, Möbius, was collected, by the " Pieter Faure " off the coast of Cape Colony (Algoa Bay), and off the coast of Natal (Port Shepstone), and Umkomass River mouth, in shallow water, and also at other localities.

Spongioderma Chuni, Kükth., has also been recorded from off the coast of South Africa.—Spec. dub. *Dendrogorgia capensis*, J. Simpson, Algoa Bay,

and off Bird Island, South Africa. (The name Dendrogorgia has been changed by Kükenthal to Spongioderma.)

Genus ANTHOTHELA.

The distribution of this genus is mainly the North Atlantic, in the deep littoral and coast abyssal, but the occurrence of a species off the Cape is of interest. — *Anthothela parviflora*, St. Thomson, off Cape Recife, Cape Colony, at a depth of 256 fathoms ; off Algoa Bay at a depth of 100 fathoms. The other species of this genus recorded are *Anthothela grandiflora* (Sars), Verrill., from the west coast of Norway, Newfoundland, and east coast of North America in the deep littoral and coast abyssal.—*Anthothela argentea*, Th. Studer, from the west coast of America, at a depth of 1559 metres.

Family MELITODIDAE.

Genus MELITODES.

The distribution of this genus is the Indo-Pacific Ocean, from Japan to Australia, and the Sudanese Red Sea. It may be that the original centre of the genus and of the family was the Malay Archipelago, from which the species have passed to the other localities.

Melitodes esperi, W. and S., east of East London, at a depth of 22 fathoms. This species was collected during the voyage of the " Challenger " in the Torres Straits.

Melitodes nodosa, W. and S. Off Flesh Point, south-west of Mossel Bay, Cape Colony, at a depth of 20–40 fathoms. This species was collected during the voyage of the " Challenger " in the Pacific, off the New Hebrides and Japan.

Melitodes dichotoma, Pall. In shallow water, 4–6 fathoms, at Gordon's Bay, False Bay, Cape Colony. It was also collected in the Torres Straits. (" Challenger.")

Melitodes Faurii, St. Thomson. Off the coast between Port Alfred and East London, in shallow water ; off Keiskamma Point, near East London, Cape Colony, at a depth of 33 fathoms ; off Tugela River mouth, Natal, at a depth of 40 fathoms.

Melitodes grandis, St. Thomson. Off Cape Seal, near Plettenburg Bay, Cape Colony.

Melitodes africana, Kükth., Simon's Bay, South Africa, at a depth of 70 metres. (" Valdivia " Collection.)

It may be recalled that Kükenthal regards the genera Melitodes, Wrightella, Acabaria, and Euplexaura as pure Pacific. There is some

evidence, however, of a species of Wrightella having passed at the Cape into the Atlantic.

Genus MOPSELLA.

The distribution of the genus Mopsella is mainly the Pacific Ocean, in shallow water, particularly the Australian coast and the Malay Archipelago. —*Mopsella singularis*, St. Thomson. Off Cape Morgan, 47 fathoms. Nature of bottom, broken shells.

Genus ACABARIA.

This genus has a fairly extensive distribution. A large proportion of the species (about half) occur in the Malay Archipelago, but species also occur in Japanese seas, in the Red Sea, off the East African coast, and off the Cape. It is of importance that they usually occur in fairly deep water.—*Acabaria valdiviae* is recorded from the Cape of Good Hope at a depth of 318 metres. —*Acabaria* sp., off the mouth of False Bay, at a depth of 41 fathoms.

Genus WRIGHTELLA.

The area of distribution of the species is the Malay Archipelago, the Seychelles, Tonga Island, north-west Australia, and the Cape of Good Hope. It appears to be a genus of the shallow littoral.—*Wrightella trilineata*, St. Thomson. Off Umkomass River mouth, Natal, 40 fathoms, nature of bottom, broken shells and stones.—*Wrightella fragilis*, St. Thomson. In deep water, 210 fathoms, far west of the coast between Saldanha Bay and Table Bay. Nature of bottom, green sand.—*Wrightella furcata*, St. Thomson. South-east of Cape Morgan, Cape Colony, at a depth of 77 fathoms. Nature of bottom, rocks and broken shells.—*Wrightella* sp., off Tugela River mouth, Natal, 79 fathoms ; nature of bottom, rocks ; off Cape St. Blaize, Cape Colony, 39 fathoms. Nature of bottom, rocks.—*Wrightella coccinea*, Gray. Shallow water near the coast at Mossel Bay, Seychelles, Indian Ocean (" Challenger ").—The occurrence of *Wrightella fragilis* so far west is of some interest.

Family ISIDAE.

Genus CERATOISIS.

The distribution of this genus is according to Kükenthal the circum-tropical deep sea ; in another paper, however, he adds the North Pacific Ocean, but we have also *C. grayi*, recorded from the west coast of Ireland, and *C. siemensii*, Studer, from the Atlantic, at great depths. The truer

statement as regards its distribution is probably that Ceratoisis occurs in the great oceans, extending far north to Newfoundland, and far south into the Antarctic, and similarly in the east and west.—*Ceratoisis ramosa*, Hickson, off the Cape of Good Hope ; off Cove Rock, near East London. This species is only recorded from South African seas.

Kükenthal writes : " Wir können es wohl als ein gesichertes Resultat tiergeographischer Untersuchungen hinstellen, dass im allgemeinen nahe verwandte Gattungen auch in ihren Verbreitungsbezirken zusammenhängen. Das ist nun bei Primnoisis und Ceratoisis zweifellos nicht der fall. Erstere Gattung ist fast ausschliesslich antarktisch, letztere hat ihr Verbreitungs-gebiet im Atlanttischen Ocean ausschliesslich auf der nördlichen Halbkugel ; im Indopacifischen geht nur eine Art (C. rigida) südlich bis St. Paul, alle anderen bewohnen ebenfalls die nördliche Halbkugel." Thus, in one paper the author appears to lay emphasis on Ceratoisis being a circumtropical genus, in another paper on it being predominantly a genus of the northern hemisphere.

Genus ACANELLA.

The distribution of the species of this genus is to some extent circum-tropical, in the coast abyssal ; but one species occurs off Patagonia, a second off Japan, and a third in the North Atlantic ; but the chief area is apparently the Indo-Pacific Ocean. It is difficult to infer in the case of Ceratoisis and Acanella the direction in which the species have spread.—*Acanella eburnea*, Pourtalès. South-east of Cape Vacca, Cape Colony, at a depth of 40–50 fathoms ; south of Bashee River Beacon, Cape Colony, in deeper water. It has already been recorded from the West Indies and from off the Azores in deep water. The distribution is apparently somewhat similar to that of *Clavularia elongata* and *Scleranthelia musiva*, and is probably to be referred to the influence of the Benguela current. It is possible that species of this genus have passed from South Africa along the west coast. Species occur on both sides of the North Atlantic, an occurrence which may be due to a former land connection across this ocean.

Acanella africana, Kükth. Has been recorded in numerous examples from stations off the East African coast.

Chelidonisis capensis, Th. Studer (Kükth.).

Isidella capensis, Th. Studer. South Africa. 92 metres. Studer, 1878. This species occurs on the Atlantic side, and another species occurs again in the Atlantic, north of the equator ; possibly further dredgings would show the occurrence of species along the west coast of Africa.

Family MURICEIDAE.

Genus MURICEIDES.

The distribution of this genus is chiefly the following : East Indies, Japan, Azores, Patagonia, Tristan d'Acunha, and off the mouth of the Congo. It is apparently more characteristic of the Pacific and the Atlantic than of the Indian Ocean.—*Muriceides fusca*, St. Thomson. This species was collected by the " Pieter Faure," but the exact localty was obliterated. from the label.

Genus VILLOGORIA.

Species of this genus are widely distributed, occurring in the Atlantic, Indian, and Pacific Oceans.

V. mauritiensis was recorded by Hickson from off East London and previously from the Mauritius by Ridley. It may thus be an Indian Ocean form which has passed southwards.

Genus ACANTHOGORGIA.

The distribution of this genus is the Atlantic and Pacific Oceans, in the deep littoral and coast abyssal.—*Acanthogorgia armata*, Verrill, south-west of the Cape of Good Hope, at a depth of 25–32 fathoms, and off Cape Morgan, at a similar depth (currents). This species has also been recorded from the east coast of North America and from Hawaii.

The genus is apparently one usually belonging to greater depths, and in connection with this, its distribution is wide. The majority of the species occur in the Indo-Pacific, but a smaller number are found in the Atlantic, and three species in the Antarctic. It is possible that the original centre of this genus was Japanese seas, that the species passed *via* the Cape into the sub-Antarctic and the Atlantic (Bay of Biscay, the Antilles, and Newfoundland) ; in the other direction in the Pacific to Hawaii, the west coast of Central America, and the southern Pacific coast of South America.

Genus MURICELLA.

The chief area of the distribution of this genus is the North and South Pacific, especially the East Indies and the Indian Ocean, and also occurring in the Red Sea.—*Muricella ramosa*, Thomson and Henderson. Off Durnford Point, Natal, depth 45 fathoms. Thomson and Henderson first described this species from Ceylonese seas. It is thus probably a migrant southwards from the Indian Ocean.

Family PLEXAURIDAE.

Genus EUNICELLA.

This genus is distributed off the Atlantic coasts of Europe and Africa, discontinuously from Scotland to the Cape of Good Hope ; in the Mediterranean ; off Japan ; off Marquesas Island (Pacific), in the deep littoral. The distribution is discontinuous, but it has been supposed that the genus has passed along the west coast of Africa, from the Cape to the temperate northern zone, and reached the Atlantic coasts of Europe and the Mediterranean. This migration over the warm water zone may have been rendered possible by the cold ascending water which occurs on the West African coast to the high tropical littoral, and produces the same conditions as in the littoral of the southern and northern temperate zone. The Mediterranean form has perhaps passed there from the Atlantic Ocean.

Eunicella papillosa, Esper. In shallow water, off Simon's Bay, False Bay, Cape of Good Hope ; off East London, 85 fathoms. It has been recorded by Studer, Wright and Studer, Hickson, Kükenthal, and myself.—*Eunicella rigida*, Kükth., has also been recorded from St. Francis Bay, at a depth of 100 metres.—*Eunicella albicans*, Köll., has been recorded from the littoral, South Africa, and from off Cape Town by Studer.

Genus EUPLEXAURA.

The distribution of this genus is the littoral of the Indo-Pacific Ocean from the Cape of Good Hope to Japan, occurring also off West Australia, California, and a doubtful species in the Red Sea. It is probably to be regarded as having passed from the Indian Ocean to the Cape.—*Euplexaura parciclados*, W. and S., off Great Fish Point, Cape Colony, 40–50 fathoms (" Pieter Faure ") ; off Kobe, Japan, 14–92 metres (" Challenger "). —*Euplexaura media*, St. Thomson, Algoa Bay, at a depth of 17 fathoms. —*Euplexaura capensis*, Verr., off the Cape of Good Hope—a doubtful species.

Genus PSAMMOGORGIA.

The distribution of the genus Psammogorgia is Panama, San Salvador, Mexico, California, west coast of Central America, South Africa, Andaman Islands (?), Mergui Archipelago (?), New Zealand (?), and Port Darwin (?).

Psammogorgia pulchra, St. Thomson. Off Cape Morgan, Cape Colony, at a depth of 36 fathoms—the only species of this genus collected off the South African coast. It is difficult to account for the occurrence of a species of this genus in South African seas, as the other species are far distantly removed in the Pacific.

Family MALACOGORGIIDAE or CHRYSOGORGIIDAE.

Malacogorgia capensis, Hickson.

Trichogorgia capensis, Hickson (Kükenthal). Near the entrance to False Bay, Cape of Good Hope (shallow water); Algoa Bay, 26 fathoms (" Pieter Faure "). This is so far to be regarded as a South African genus.

Trichogorgia flexilis, Hickson. Off Cape Recife, South Africa (" Pieter Faure "). There is some difference of opinion in regard to the identification of certain specimens; in the one case we would have two new genera, Malacogorgia and Trichogorgia, occurring off South Africa (Hickson); in the other case we would have one new genus (Trichogorgia) with two species and a possible but doubtful related species (*Trichogorgia* or *Chrysogorgia constricta*, Hiles) occurring off New Britain and Amboina.

Family PRIMNOIDAE.

Genus STACHYODES.

This genus is distributed in the great oceans, north and south of the equator, one species occurs off Ireland, another *Stachyodes gaussi*, Kükth., occurs in the Antarctic at a depth of 2450 metres. No species are known to occur off the West African coast. It occurs in the Atlantic, Indian, Indo-Pacific, Pacific Oceans, and Japanese Seas.

Stachyodes capensis, St. Thomson. Off Cape Morgan, Cape Colony, at a depth of 77 fathoms.—*Stachyodes Gilchristi*, St. Thomson. Off Cape Vidal, Natal, at a depth of 80–100 fathoms; off Cape Morgan, Cape Colony, at a depth of 80–100 fathoms. Kükenthal has made reference to a species, *Stachyodes gilberti*, St. Thomson; but I have never described or recorded a species by that name.

The record of species from the Cape Colony and Natal falls into line with the occurrence of species in the Indian Ocean.

Genus THOUARELLA.

The distribution of this genus is the sub-Antarctic area, the South Atlantic, and South Pacific, the Indian Ocean and extending far north off the east Asiatic coast to Japan. Some twenty-four species of Thouarella have been recorded, including *Thouarella* (*Euthouarella*) *flabellata*, Kükth., off the East African coast, at a depth of 1644 metres.—*Thouarella* (*Parathouarella*) *versluysii*, Kükth., on the Agulhas Bank, at a depth of 500 metres.— *Thouarella* (*Parathouarella*) *clavata*, Kükth., on the Agulhas Bank, at a depth of 500 metres.

Thouarella Hicksonii, St. Thomson. South-west of Cape St. Francis, Cape Colony, at a depth of 74 fathoms. This occurrence at the Cape is probably to be regarded as indicating a connection with the Antarctic.

Family GORGONIIDAE.

Genus LEPTOGORGIA.

Some sixty species of this genus have been recorded from various localities in the Atlantic, Pacific, and Indian Oceans, not usually far north or far south. A number of species have been described from the east and west coasts of America. As a locality, not so far removed from that surveyed by the " Pieter Faure," mention may be made of *Leptogorgia ochracea*, off Zanzibar. The point of interest in this connection is that a species occurs off the east coast of Africa, species off South Africa, and species off West Africa, thus indicating the possibility of a migration round the coast.

Leptogorgia africana, St. Thomson. Off Cove Rock, East London, Cape Colony, at a depth of 43 fathoms.—*Leptogorgia alba, var. capensis*, St. Thomson—*Leptogorgia alba, var. natalensis*, St. Thomson. Off Durnford Point, Natal, at a depth of 45 fathoms.—*Leptogorgia rigida*, Verr., off East London, Cape Colony, at a depth of 85 fathoms.—*Leptogorgia aurata*, St. Thomson. Off Umhloti River mouth at a depth of 40 fathoms. *Leptogorgia abietina*, Kükth. Francis Bay, South Africa, depth 100 metres (" Valdivia "). *Leptogorgia tenuissima*, Kükth. Francis Bay, South Africa, depth about 100 metres (" Valdivia ").—*Leptogorgia pusilla*, Kükth. Francis Bay, South Africa, depth 100 metres (" Valdivia ").

Thus it will be seen that species of the genus Leptogorgia appear to flourish off the South African coasts. It is also one of the most prevalent species on the west coast of Africa.

Genus LOPHOGORGIA.

This genus has been recorded off the South African coasts, the Gulf of Guinea, off Gaboon, Sierra Leone ; species have not been described from the more northern nor more southern seas. In this case, again, a dispersal might be inferred, probably with the aid of currents from South Africa along the west coast of that continent.—*Lophogorgia Lütkenii*, W. and S., off Gordon's Bay, False Bay, Cape Colony, 4–6 fathoms (" Pieter Faure ").—*Lophogorgia crista*, Möb. St. Francis Bay, at a depth of 100 metres (" Valdivia ").

Genus GORGONIA.

The distribution of this genus is rather uncertain, owing to doubt as to the correct determination of a number of species. The more certain localities

appear to be Mexico, Panama, Cape St. Lucas, La Paz., Peru, Ecuador, Gulf of California.[1] Gorgonia possibly occurs off New Zealand, in the East Indies, and at a number of other localities such as the Indian Ocean and the Mediterranean. Three species have been recorded from South African seas.

Gorgonia flammea, E. and S. Is common in shallow water, at a number of localities off the South African coast, such as False Bay and Mossel Bay. It may be regarded as a true Cape of Good Hope species.—*Gorgonia albicans*, Köll., in shallow water, False Bay, off Port Alfred and off Cape St. Blaize, Cape Colony.—*Gorgonia capensis*, Hickson. Mossel Bay, Cape Colony, at a depth of 40 fathoms. Off Knysna Head, at a depth of 35–49 fathoms, on a sandy and muddy bottom.—*Gorgonia sp.*, near Robben Island, off Table Bay.

Genus EUGORGIA.

The localities of the nine or ten species of this genus are off the coasts of California and Peru, off the coasts of La Paz, Mexico, Panama, Nicaragua, Ecuador, and off the South African coast. The peculiar point is that the Cape species are far isolated from those occurring in other areas.—*Eugorgia Gilchristi*, Hickson, off Cape Recife, Cape Colony, at a depth of 52 fathoms. —*Eugorgia lineata*, St. Thomson, off Cape St. Blaize, at a depth of 15–18 fathoms, and off Nanquas Peak. It is striking that the other species of Eugorgia should be from the western coast of the United States, Central, and South America.

Genus STENOGORGIA.

The distribution of this genus is off parts of the east coast of the United States, off the coast of Scandinavia, off Guadeloupe (West Indies), off the Antilles, off the Azores, off the Sombrero Canal (Indian Ocean), the Sunda or Flores Sea (East Indies), off the Congo River mouth, off the Faroe Islands, and off California.

Stenogorgia capensis, St. Thomson. Off Roman Rock, Algoa Bay, Cape Colony, at a depth of 20–30 fathoms. The occurrence of this species is perhaps to be linked with the occurrence of a species in the Atlantic off the west coast of Africa (Azores). This is the nearest locality in which the species is known to occur.

Family GORGONELLIDAE.

Genus SCIRPEARIA.

This genus was emended by Simpson in 1910, and he proposed to bring under the generic name Scirpearia, three others, namely Scirpearella,

Ellisella, and Ctenocella. In his emended list of species of Scirpearia
we have the following distribution :—

S. profunda, off the New Hebrides ; *S. gracilis*, off the New Hebrides ;
S. rubra, off Hyalonema ground, Japan ; *S. furcata*, off Torres Straits ;
S. elongata, off the West Indies ; *S. flagellum*, off the Azores ; *S. Thomsoni*,
off the Bay of Bengal ; *S. aurantiaca*, off Ceylon ; *S. moniliforme*, off the
Andamans.

Species of the genus Scirpearia as emended by Simpson occur in the
Atlantic, Mediterranean, Indian, and Pacific Oceans. It will not do to
state, as he does, immediately after showing to the contrary, that " this
genus is entirely restricted, with the exception of *S. flagellum*, so far as the
present records show, to the Pacific Ocean." In the case of the South
African species, a link with the Indian Ocean appears to be indicated,
though species also occur in the Atlantic.

Scirpearia furcata, Hickson, emend. Simpson. Algoa Bay, Cape Colony,
shallow water, 20–30 fathoms ; off East London, Cape Colony, shallow
water, 52 fathoms ; off Cape Morgan, depth 36 fathoms ; off Umhlangakulu
River mouth, Natal, depth 50 fathoms ; south-east of Tugela River mouth,
Natal, depth 47 fathoms ; off Cone Point, Natal, depth 34 fathoms ; off
Hood Point, 42 fathoms. This species, as emended by Simpson, has been
recorded from Ceylon, Maldives, Andamans, Malabar, Mergui Archipelago,
Burma, and various localities off Cape Colony and Natal.

Scirpearia flagellum, em. Simpson.

Juncella flagellum, Johnson. Off Buffalo River, East London ; south-
east of Tugela River mouth, Natal, depth 62 fathoms. This species as
emended by Simpson has been recorded from the Azores, Barbadoes,
Mediterranean, South Africa. There is considerable risk in stating the
distribution of the species of the genus Scirpearia and of allied genera, as
there is difference of opinion in regard to the synonomy. Simpson's work,
" A Revision of the Gorgonellidæ, I, The Juncellid Group," may be referred
to, but the conclusions drawn are apparently not accepted by Kükenthal
and Toeplitz (MS.).

The occurrence of three species of *Hicksonella*, Simps., may be noted,
namely *H. spiralis* (S. Africa), *H. flagellata* (S. Africa), and *H. capensis*
(S. Africa and Natal).

Verrucella bicolor, Nutting. Off Tugela River mouth, Natal, at a depth
of 65–80 fathoms ; off Amatikulu River mouth, Natal, at a depth of 62
fathoms. This species was recorded by Nutting from near the Hawaiian
Islands. Other species of the genus have been recorded from New Britain,
Funafuti, the Red Sea, Mauritius, and other parts of the Indian Ocean.

PENNATULACEA.

Family VERETILLIDAE.

Genus ACTINOPTILUM.

This genus has not so far been recorded elsewhere than off the coasts of South Africa.

Actinoptilum molle, Kükth.

Cavernularia obesa and *Cavernularia elegans*, Hickson. This is one of the commonest and most characteristic species, occurring in shallow water, as shown by the dredgings of the " Pieter Faure," very plentifully and show-ing great variation. It occurs at a number of localities off the south and east coasts of Cape Colony and Natal. It is noteworthy that it occurs in colder water of Table Bay as well as in the warmer of Algoa Bay and False Bay. The close relationship with Echinoptilum has to be noticed, a genus which occurs in the Indian Ocean, the Pacific Ocean, and in Japanese seas.

Genus CAVERNULARIA.

The distribution of this genus is the Mediterranean, Madeira, west coast of Africa, Indian Ocean, Sunda Islands, China, Japan, east coast of Australia and Polynesia, in the shallow littoral.

Cavernularia Lütkenii, Köll. Off the mouth of the Tugela River, at a depth of 12–14 fathoms ("Pieter Faure "). This species had previously been recorded by Kölliker and by Thomson and Simpson from localities in the Indian Ocean ; it is therefore interesting to find it occurring off the coast of Natal, which is washed by the warm (Mozambique) current from the Indian Ocean.

Family VIRGULARIIDAE.

Genus VIRGULARIA.

The distribution of this genus is very extensive. It occurs in the Indian Ocean, Malay and Australian seas, Japanese seas, Californian seas, Magel-lanic Sea, off New Zealand and S.E. Australia. Its absence from a belt in the Antarctic, north and south of the equator may be noted.

Virgularia Schultzei, Kükth.

Virgularia Reinwardti, Hickson. Saldanha Bay in 10–40 fathoms ; off Cape Point Lighthouse in 45 fathoms ; St. Francis Bay in 30 fathoms (" Pieter Faure "). This species was also collected in Plettenburg Bay,

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South Africa, at a depth of 100 metres (" Valdivia ") ; in Luderitz Bay, British South-West Africa (Schultz Collection). The distribution of this species seems to indicate a dispersal from South Africa to the west coast.

Family ANTHOPTILIDAE.

Genus ANTHOPTILUM.

The distribution of this genus is the Pacific, Indian, and Atlantic Oceans at great depths.

> *Anthoptilum grandiflorum*, Verr.
> *Virgularia grandiflora*, Verrill.
> *Anthoptilum grandiflorum*, Jungersen.
> *Anthoptilum grandiflorum*, Hickson.

Off Lion's Head at a depth of 190 fathoms. The following notes by Gilchrist may be given : " The colour when fresh was a uniform bright brick red. Fifty-four specimens were obtained on 28th March 1900 at the above locality. They seem to occur in great abundance . . . probably forming miniature forests at the bottom of the sea." This species is also recorded from the North Atlantic, on the west coast of America and Canada. Its occurrence at the Cape on the Atlantic side of the Cape Peninsula to some slight extent may bear out Hickson's opinion that the forms described from the Indian Ocean (" Valdivia ") by Kükenthal and Broch, are not rightly to be regarded as examples of *Anthoptilum grandiflorum*, but rather as a separate species, *Anthoptilum Kükenthali*. The species in Hickson's sense is thus to be regarded as a deep-water one, occurring, so far as we know, only in the North and South Atlantic.

Family UMBELLULIDAE.

Genus UMBELLULA.

A cosmopolitan distribution in the deep sea.—*Umbellula aciculifera*, St. Thomson. Off Cape Point at a depth of 100–900 fathoms (" Pieter Faure ").

Family PTEROEIDIDAE.

Genus PTEROEIDES.

The distribution of this genus is the Asiatic coast of the Pacific, the East Indies, Australia, Indian Ocean, Mediterranean, and southern Atlantic coast of Europe. It is a shallow-water form.

Two species of Pteroeides were collected by the " Pieter Faure " ; one is

too unsatisfactory for identification ; the other, *Pteroeides isosceles*, St. Thomson, off Bird Island, East London, at a depth of 32–38 fathoms. The occurrence of species of Pteroeides farther north, off the east coast of Africa, may be noted in this connection.

<div align="center">Family FUNICULINIDAE.</div>

<div align="center">Genus FUNICULINA.</div>

The distribution of the genus Funiculina is the North Atlantic and Indian Oceans, Japan, New Zealand ; in the abyssal and deep-sea littoral.— *Funiculina quadrangularis*, Pall, off Cape Vidal, Natal, at a depth of 80–100 fathoms. This species has a wide distribution, namely the North Atlantic, the Mediterranean, Indian Ocean (East African coast, Pemba Canal, Bay of Bengal), and in the Pacific Ocean, Japan, New Zealand. It is apparently a form which is independent of variations in temperature and pressure— similarly, *Anthoptilum grandiflorum* seems equally independent of variations in pressure.

An attempt at a comparison of the Pennatulids occurring off the west coast of Africa with those of the Indo-Pacific has been made by Balss. Unfortunately the data for the former area are far from complete. Balss writes that there is a sharp distinction of the west coast of Africa from the Indo-Pacific at the Cape ; that the Veretillidæ are characteristic of the Indian Ocean. Kükenthal points out that this does not hold, as genera of this family occur in the Atlantic, also that *Cavernularia elegans* occurs in the Indian Ocean, but also off the west coast of Africa. Kükenthal is also against the supposition that forms may pass from the Indian Ocean into the Mediterranean *via* the Red Sea, and from the Mediterranean into the Atlantic.

It is evident that there is a harvest to be reaped, though perhaps only in the distant future, by charting and comparing the distribution of marine animals, and the foregoing is only an endeavour to follow along the same lines as those of Hickson for the Siboga Expedition, and Kükenthal for the " Valdivia " explorations.

In regard to the literature, in order to reduce the letterpress, I have not added a bibliography of all the papers consulted, but reference may be made

to the lists in Professor Kükenthal's Memoirs on the Alcyonacea, Gorgonacea and Pennatulacea of the " Valdivia " expedition, and to the following papers dealing more specially with South African Alcyonaria :—

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EXPLANATION OF CHARTS.

Chart I.—Distribution of Alcyonaria indicated on an Admiralty Chart between latitudes 34°–45′ and 32°.

Chart II.—Distribution of Alcyonaria indicated on an Admiralty Chart between latitudes 32° and 28°.

The localities were in the first case taken from the " Pieter Faure " dredging book, in which they were usually given as the ship's bearings at the time when the dredge or trawl was taken. These localities are given in Hickson's and in my previous papers (see list). In some cases, the species are not entered in the Chart, owing to lack of space, and no doubt there are still undescribed species in the Cape Town Museum.

Wolf's

Muishock
Hutje Berg
Vort
Nian En
1890

Duarsaarsbaai

Hopefield

Kwart Berg

Darling

Malmesbury

Garden
Berg

Wol

Olifants Kop

Paarl

Di'Mas
Voorbij

Stellenbosch   Zonder End Vly

Table H.

Cape Town

Somerset

Simons

Caledon

OF GOOD HOPE

Bredasdorp

Walker B.

Sebastian R.

Surys Bay

Actinoptilum molle

Melitodes dichotoma

Virgularia Reinwardti

Cape Aghulhas

Between Cape Hanglip and Cape

ALGOA BAY

Actinoptilum molle

Acrophytum c

Alcyonium pachyclados · Alcyo

Melitodes grandis

Metalcyonium variabile

Wrightella coccinea

Actinoptilum molle — Eryth

Wrightella sp.

Thouarella Hicksoni

Gorgonia ca

Gorgonia albicans

Alcyonium purpureum

Virgularia Reinwardti

Metalcyonium variable

Trichogorgia fr

Anthothela parvi

Anthomastu

Metalcyonium

Huninsdorp

C. St. Francis

St. Francis B.

Occasional

Mopsella angularis

Melitodes E...

Actinoptilum molle

Metalcyonium variabile

Sarcophytum trochi...

Villogorgia mauritiensis.

Sclei...

Scirpearia furcata

Eunicella papillosa

Actinoptilum molle

Leptogorgia rigida

Certoisis ramosa

Metalcyonium variabile

Scirpearia flagellum

Melitodes Faurii

Alcyonium rotiferum

Anthomast...

Leptogorgia africa...

Alcyonium purpureum

Actinoptilum molle

Euplexaura pariciados

Malacanthus rufus

Melitodes lanceatum

Gorgonia albicans

Actinoptilum molle

Pteroeides sp.

Actinoptilum molle

Bellonella Studeri

Scirpearia furcata

Actinoptilum molle

Malacogorgia capensis

...phytum claviger

Pteroeides isosceles

Euplexaura media

Erythropodium membranaceum

Anthothela parviflora

...clados Alcyonium purpureum

Spongioderma verrucosum

...chogorgia flexili...

...la parvi...

Chart I.

Acanella eburnea

Alcyonium purpureum

Metalcyonium variabile

Sinularia unilobata

Stachyodes Gilchristi

Scirpearia furcata

Psammogorgia pulchra

Metalcyonium variabile
Acrophytum claviger

Erythropodium foliatum

Suberia capensis
Metalcyonium variabile
Acanthogorgia armata

Psammogorgia pulchra
Wrightella furcata
Juncella spiralis
Stachyodes capensis
Metalcyonium variabile
Sinularia unilobata

Melitodes Esperi

variabile Scleranthelia musiva

phytum trochiforme

noptilum molle

Anthomastus granulosus Sinularia unilobata
eptogorgia africana

Sinularia unilobata

33°

195
5 m

200
s m

308

205
m

Jacob IC.

Saldanha R.

Masson Bay
Hopefield

Oudbock
Groote Ewart Bay

15'

153

52
cr.

246

113
s m

210
m

125

Darling

70

Ijzer Fontein P⁶.

Malmer

Dassen I⁶.

30'

1480

1020

520
gras :

434
gras.o

307

304

240
s m

150
s m.o

105
s

85
vo.s

40

Hoe P⁶.

530

420

360

120
m

Wrightella fragilis

110
m

Gorgonia sp.

45'

Actinoptilum molle

Kobven
I. Occ. 1548
(Eng sig⁴)

Alcyonium Sollasi

34°

Anthelia capensis

Cape Town

Anthoptilum grandiflorum

Dayhar P⁶.

Malacanthus rufus

(WT. Time Sig.⁽¹⁾) Simonstown

15'

Anthoptilum grandiflorum

Alb

30'

C. OF GOOD HOPE

Metalcyonium novarae

200
g.s

186
2

462

145

208

Actinoptilum molle

Melitodes dichotoma

Virgularia

45'

Clavularia

1 to

Icebrg
orangi

Alcyonium purpureum

Lophogorgia Lütkenii

Melitodes dichotoma

35°

1250
s.s

Actinoptilum molle

Actinopti

15'

Heteroxenia capensis

Eunicella papillosa

Ceratoisis ramosa

Acanthogorgia armata

Metalcyonium variabile

Malacogorgia capensis

Malacanthus rufus

30'

1504

45'

Acabaria sp

Map Soberys some 10
seas have in two

36°

Almesbury

Garden Berg

Wei

Olifants Kop

Dryaang

Stellenbosh   Zonder End

Somerse

Caledon

Sebastian R.

Ch Infants

Bredasdorp

Walker B.

Struys Bay

Sandy Pt

Quoin Pt

C. Agulhas

Clavularia elongata

Between Cape Hanghip and Cape
Agulhas the current occasionally
sets E.S.E. at the rate of a mile an hour

Actinoptilum molle

Gorgonia albicans

Virgularia leinhardti

Melitodes dichotoma

currents generally
weak and variable

Alcyonium pachyclados

Alcyonium valdiviae

½ to 1 kn.

Gorgonia capensis

Erythropodium membranaceum A. pachyclados

Alcyonium purpureum

Metalcyonium variabile

Xenia florida

Eugorgia lineata

Meltodes nodosa

Gorgonia flammea

Acanella ebyrnea

Thouarella Hicksoni

ria elongata

hyclados

valdiviae

Muizenberg Ir.

Melit

Metalcyonium var

Wrightella coccinea

occasional

Actinoptilum molle

Erythrop

Slug Bank
(rep. 1917)

Shoaler

1 to 24 km

SOUTH AFRICA

CAPE OF GOOD

AND ADJACENT COAST

ALGOA BAY

Actinoptilium
Scirpearia furcata
Actinoptilium molle
Acrophytum claviger
Malacogorg
Euplexaura me
Erythropodium me
Anthothela parviflo
Spongioderma verrucosum
Alcyonium pachyclados Alcyonium purpureum
Trichogorgia flexilis
Stenog
Melitodes grandis
Gorgonia albicans
Alcyonium purpureum
Metalcyonium variabile
Virgularia Reinwardti
Anthothela parviflora
Anthomastus grandiflorus
m variabile
Wrightella sp.
Thouarella Hicksoni
Metalcyonium variabile
Gorgonia capensis
Erythropodium Wilsoni
thropodium membranaceum

D HOPE

ASTS

L H A

Erythropodium foliatum

Suberia capensis
Metalcyonium variabile
Acanthogorgia armata

...des Esperi

Scleranthelia musiva

...rochiforme

...molle

...omastus granulosus
...a africana

Sinularia unilobata

Psammogorgia pulchra
Wrightella furcata
Juncella spiralis
Stachyodes capensis
Metalcyonium variabile
Sinularia unilobata

4 to 14 km occasionally

Neill & Co., Ltd

Chart II.

Mashlaline - Goolss?

Mhlongashiang

Cape Vidal

Umbusgra Hill

Mavanb Hill

ULUNDI Ombumbangwene

Samkela

Umvolosi Riv

Remarkable

Sharp topped hill

Conical Hill

Mendu Hills

St Lucia Bay

Inseleni River

Nsobo

Mdave Hill

C St Lucia

Sharp Pt

Malausana Range

Hlabana L.

Black Bluff

Emhlangubo

Laggoon

F. Richards

Durnford Bay

High steep hills

St Andr

Matikalu Riv

High bare hills

Walmesly Hill

Nonoti

Ngyoni Riv

Tugela R.

Ingang

Sinkwassi R.

Nonoti R.

Umhlutane

Elephant Kop

Umvoti R.

Umhlali R.

Tong

Uguloti R.

Umhli R.

NATAL

Natal (Sea Flat)

Umbogat

Illovo

Umgeni

NATAL

Funiculina quadrangularis

Stachyodes Gilchristi

Acanthogorgia sp

Mopsella singularis

Muricella ramosa

Leptogorgia alba

Leptogorgia aurata

Acrophytum claviger

Acrophytum claviger

Cavernularia Lütkenii

Alcyonium sarcophytoides

CAUTION

Between the Tugela & Umlalazi Rivers, during May
to July (1911) a current of ½ to 1 knot per hour was
experienced as far as 20 miles from land setting
to the N N W or directly towards shore
HMS Mutine (1911)

1280

Alcyonium purpureum

Verrucella bicolor

Metalcyonium variabile

Metalcyonium clavatum

Metalcyonium variabile

Acrophytum claviger

Sarcophytum trochiforme

Verrucella bicolor

Sarcophytum trochiforme

Scirpearia furcata

Scirpearia flagellum

Metalcyonium molle

Metalcyonium clavatum

Melitodes Faurii

Acrophytum claviger

1580

trochiforme

Alcyonium glomeratum

Leptogorgia sp

Anthomastus elegans

Sinularia unilobata

Scirpearia furcata

Wrightella sp.

W. trilineata

S. verrucosum

Bellonella Studeri

Sarcophytum trochiforme

Acrophytum claviger

Sinularia unilobata

tum claviger Spongioderma verrucosum

TRUE

30'

29°

30'

30'

30°

30'

31°

30'

32°

KAFFIRLAND

ZULU

NATAL

Ingang

Mohna (1183)

Elephant

Inanda (1859)

Verala

Umgeni R.

Pine Town (170)

PORT NATAL

Umlazi R.

Bovella (1388)

Umsimbara R.

Umkomaas R.

Illovo

Amhlongwa R.

Emburgga (1668)

St
William

Green S.

Saininto

Ifafa (916)

Umsimayo R.

Ifafa R.

Umbegalane R.

Copper Hill

Umsumayjo R.
900
m.st.

Kali (2037)

Umnonbo R.

Umsimkulu (1700)

Murchison (1889)

Emientweeni R.

Imbinama R.

Shepton

Umsinkulu R.

Ibooi

Acrophytum claviger

Inga (1900)

Umzinkulu

Ingenjali R.

Umtamvuna R.

Umbengeni

Ibe

Telesto R.

Scinearia furcata

Telesto arborea

Umyanami (1539)

Inkonbi R.

Umba

Paten (1523)

Cunto

Umti

Red Hill

Mikota R.

Fossil I.

St John or
Umzimvuba R.

Umpatami R.

Iloff (1056)

Ikan

Igasi

S'th Sand Bluff

Ubasi R.

Umgazi R.

Ekwahn R.

Umgazian R.

Iba

Waterfall Bluff

Embotyi R.

Umsimklava R.

Umtakatyi R.

Beacon Hill (1740)

Meston (1880)

Entafoni R.

St John Rd

Gordon B. L'Flash (ev 3 sec)
vis 20 m.

Umtata (1388)

Sugarloaf Rk

Morley (2037)

Bazen Hd

Egwahani R.

Rame Hd

Ubomeo Hd

Mpako R.

Umdivala

Whalebh

1650
s.m.

90 miles off

2 knots

prawn

Strong current along this line of coast from
occasionally uncertain but generally sets to the

2½ m.

Conical Hill

Umvolosi Ri.
Remarkable sharp-topped hill
St Lucia Bay

Mendu Hills
Mdavo Hill
Inseleni River
Imbani R.
Nsobe
Sharp Pk
C. St Lucia
L'Double

Makusana Range
Hlabana L.

Black Bluff

Emhlangubo
Kam.
Lagoon
F. Richards
St Richards Bay
Burnford Pt.

High steep hills
Umlalazi
Durnford Bay

High bare hills
Figton Reef

St Andre
St Paul
Matikalu Riv.
Walmersley Hill
Nonoti
Dyoni Riv.

Ingangwen
Sinkwazi R.
Nonoti R.
Umhlutane
Umvoti R.
Umhlali R.

Mohna
Albert
Tong.

Elephant
Inanda
Veralam
Umgeni R.
Uphlot R.

PORT NATAL
Umhlatuzana
Umbilo
Natal (See Plan)

Umbogat
Illova
Umk.
Isimansir
Ulu R.
Umn.
vana R.

Green
W. trilineata
S. verrucosum
Umsimayo R.

Bellonella Studeri
Fafa R.
Coppel Hill
simayo R.

Green R.
lu R.

phytum claviger Spongioderma verrucosum

Acanthogorgia sp.
Mopsella singularis
Muricella ramosa
Leptogorgia alba
Leptogorgia aurata
Acrophytum claviger
Acrophytum claviger
Cavernularia Lütkenii

Alcyonium sarcophytoides

CAUTION
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Alcyonium purpureum

Verrucella bicolor
Metalcyonium variabile
Sarcophytum trochiforme
Scirpearia furcata
Scirpearia flagellum

Metalcyonium clavatum
Acrophytum claviger
Sarcophytum trochiforme
Metalcyonium variabile
Verrucella bicolor

Metalcyonium molle
Metalcyonium clavatum
Acrophytum claviger

Melitodes Faurii

Alcyonium glomeratum
Leptogorgia sp.

Anthomastus elegans
Sinularia unilobata
Scirpearia furcata
Wrightella sp.

Sarcophytum trochiforme
Acrophytum claviger
Sinularia unilobata

1280

1580

TRUE

Neill & Co., Ltd.

A NOTE ON THE PROPAGATION OF HEAT IN WATER.

By J. R. Sutton.

This paper is a brief discussion of some of the results obtained from hourly observations of the temperature of the water contained in a cemented brick cistern 7 feet square and 30 inches deep. The centre of the cistern is occupied by an evaporation tank to which the cistern acts as a guard ring. The water is ordinary river water and not very clear. The period of observation is eighty-two winter days between May 26 and August 31, 1922. Eight of the days were cloudy enough to hinder the sun's rays materially, and on six of them there were a few drops of rain; seven other days were moderately cloudy; the rest were clear, or there was cirrus in the sky. The sun could shine on the water from about X to XVI; before and after these hours trees interfered more or less with a low sun.

Thermometer readings of the surface and bottom of the water were taken every hour from VIII to midnight, occasional gaps (chiefly at noon) being interpolated in the usual way. The thermometer used for the surface temperatures had a bright naked bulb. In taking a reading, the bulb was immersed just under the surface and kept there until the height of the mercury column was stationary. This operation required considerable care, since too much agitation of the water mixed its surface layer with that below, lowering the reading considerably during the heat of the day (by as much as 2° sometimes), and raising it somewhat at night. For the bottom temperatures an ordinary slow-action earth thermometer was used, its bulb being enclosed in wax. It was allowed to lie horizontally on the floor of the cistern, and was raised or lowered by means of a cord.

For purposes of comparison, hourly observations were also taken of the temperature of the water in a copper drum standing on the ground in the shade of a louvred screen. The drum is about 22 inches high and 15 inches in diameter at the top.

The results are shown in Table I. From I to VII the water values are interpolated on the assumption (which seems to be justifiable) that the fall of the temperatures between midnight and sunrise is uniform. The shade temperatures for the same hours are taken from the automatic records. They refer to temperatures taken some distance away in a large screen.

The surface of the water in the cistern shows a curve of temperature with single maximum and minimum turning points, the former falling about half an hour earlier than that of the air, and a range of about 10° F.

The bottom of the cistern shows a curve of temperature with a double maximum, one at XV, the other at XXII. The second minimum, between XVI and XVII, is small but quite definite. It is very noticeable on some clear days, and appears to fall later slowly as the season advances.

Taking the mean of the temperatures of the top and bottom of the cistern as representative of the average temperature of the whole body of water, the rise in six hours to the maximum is half as rapid again as the following fall of the same duration.

The following are the highest mean hourly temperatures observed :—

	Shade.	Cistern.		Screened Drum.
		Surface.	Bottom.	
	°	°	′	°
May 26 to June 30 . .	62·9	55 7	51·0	53·5
July	68·0	58·0	49·7	57·1
August	69·6	61·1	52 8	58 8

The amplitudes and phase angles in the sine series, calculated from the hourly values of Table I, are given in Table II. The formula is

$$T = t + a_1 \sin (A_1 + n15)$$
$$+ a_2 \sin (A_2 + 2n15)$$
$$+ \ . \ . \ .$$

The first thing to be noticed in Table II is that none of the water terms show any obvious dependence upon those of the air. The case of the screened drum is conspicuous, seeing that its temperature is derived in the first instance entirely from the air. Only its fourth harmonic term has a phase

time anywhere near that of the shade temperature ; but whereas the amplitude of the fourth shade temperature term is large, that of the water temperature term is small.

The second thing is that the ratio $a_1 : a_2$ is practically the same for the shade temperature, the bottom of the cistern, and the screened drum.

But the chief interest of Table II is concerned in the comparison between the amplitudes and phase times of the surface and bottom temperatures of the cistern, especially since it must apply in principle to bodies of water in general. It is evident that the heat supplied to the water of the cistern may be divided into two parts : one in which the whole body of water is heated nearly simultaneously (chiefly by the sun's rays, of course), the other by virtue of which the surface temperature is propagated downwards as a wave. The A_1 term has its maximum influence on the surface at 15 h. 24 m. ; the A_2, A_3, and A_4 terms have maxima very close together between 13 h. 35 m. and 14 h. 6 m. ; even the A_6 term ($a_6 = \cdot 269$) is not much later, *i.e.* at 14 h. 46 m. The A_2, A_3, A_4 terms represent the nearly simultaneous heating of the water throughout. Their epochs appear to fall a little earlier at the bottom than they do at the surface ; and if this be not due to accidental errors of observation, or perhaps to surface disturbance due to wind, it may arise from a certain amount of outward radiation from the surface. The A_1 term represents the temperature derived from heating by sun and air together, the air effect (judging by the phase time of the same term for the screened drum) helping to make it as late as it is. The twenty-four-hour wave of temperature travels slowly downwards through the water, taking 4 h. 6 m. to cover the 30 inches of depth, or, say, a little over 7 inches an hour.

As bearing on the question of the nearly simultaneous heating of the water throughout, I venture to quote some results contributed to the Proceedings of the South African Society of Civil Engineers : During 1917 a black bulb *in vacuo* thermometer was exposed side by side with an open black bulb thermometer at a depth of 18 inches in the cistern, in such a position that the sun shone on both equally. Mean results were :—

	Black Bulb *in vacuo.* Mean Max. °	Open Black Bulb. Mean Max. °
March . . .	77·0	74·5
July . . .	51·1	47·6
August . .	55·8	51·4
September . .	65·7	61·6

Some hourly observations of earth temperatures at depths of 1 and 2 feet, at a distance of about 40 feet from the cistern, were taken on eight days in August during the eight hours, XVII to midnight. They compare as follows with the synchronous water temperatures :—

		Earth.		Water.	
		1 ft.	2 ft.	Surface.	Bottom.
		°	°	°	°
XVII	.	57·1	58·0	54·6	50·5
XVIII	.	57·3	58·1	52·6	50·7
XIX	.	57·3	58·1	52·2	50·7
XX	.	57·3	58·1	51·5	50·8
XXI	.	57·0	58·1	50·9	50·8
XXII	.	56·8	58·2	50·5	50·7
XXIII	.	56·5	58·2	50·1	50·6
Midnight	.	56·2	58·2	49·8	50·6

The deeper earth temperatures continue to rise while the shallower ones are falling, albeit the latter are wholly the lower throughout the day. We have, in fact, the propagation of a cold wave downwards into a warmer medium ; the pulsation being almost exactly the same in aspect and time as it is at midsummer when the shallower level is the warmer and a warm wave of temperature is therefore passing into a colder medium. With water there is a difference. A warm wave may be propagated downwards, but not a cold one. A cold wave is damped very quickly by convection currents and so lost. Comparing the temperatures of the surface and bottom of the cistern day by day, it is found that while the temperature of the surface falls after sunset, that of the bottom rises until the two are nearly the same. The bottom temperature then remains about stationary for some hours, while that of the surface continues to fall until it is $1°·2$ the lower. From then onwards until after sunrise the surface and bottom temperatures fall at the same rate, *i.e.* the temperature gradient remains constant between midnight and sunrise.

In interpreting these results it should be remembered that the bulb of the thermometer used for the " surface " temperatures is three-eighths of an inch in diameter, and hence that its indications integrate the temperatures throughout that depth of water. Of the temperature of the true surface film of still water it tells us nothing. The researches of Tyndall and others have shown that water is a good absorber of the longer heat waves ; and it seems not unlikely, from various considerations, that the temperature of the surface film cannot be greatly different from that of moving air in

contact with it,* and that the temperature gradients near the times of maximum and minimum air temperatures may be very steep in the first millimetre or so of depth.†

TABLE I.—*Hourly Temperatures.*

Hour.	Shade.	Surface of Cistern. S.	Bottom of Cistern. B.	$\frac{S+B}{2}$	Screened Drum.
	°	°	°	°	°
Midnight . .	45·8	50 0	51·0	50 5	50·2
I . . .	44·6	49·8	50·9	50·4	49·5
II . . .	43·7	49·6	50·8	50·2	48·8
III . .	42·7	49·4	50 6	50 0	48·1
IV . .	42·0	49·2	50·4	49·8	47·4
V . . .	41·2	49·0	50·2	49 6	46·7
VI . .	40 6	48·8	50 0	49 4	46·0
VII . .	40 5	48·6	49·8	49·2	45·3
VIII . .	46·4	48·4	49·7	49 0	45·4
IX . .	52·9	49 0	49·7	49·4	46·4
X . . .	57·6	50 1	49·7	49·9	47·7
XI . .	61·6	52·4	50 0	51·2	49·2
Noon . .	64·2	54·7	50 4	52 5	51·4
XIII . .	65·9	57·4	50·7	54·1	53·6
XIV . .	66·7	58·3	50·9	54·6	55·0
XV . .	66·8	57·8	51·0	54·4	56·2
XVI . .	65·8	55·4	50·9	53·1	56·3
XVII . .	61·6	54·0	50·9	52 5	55·6
XVIII . .	55·6	53 0	51·0	52·0	54·7
XIX . .	52·7	52 0	51·1	51·5	53·8
XX . .	51·0	51·4	51·1	51·2	53·0
XXI . .	49·4	50·9	51·1	51·0	52·3
XXII . .	48·1	50 5	51·2	50 8	51·6
XXIII . .	47·0	50·2	51·1	50·6	50·9
Mean . .	52·3	51·7	50·6	51·2	50·6
Range . .	26·3	9·9	1·5	5·6	11·0

* *Cf.* Sutton, " The Control of Evaporation by the Temperature of the Air," Trans. R. Soc. S. Africa.   In the Press.

† *Cf.* Wilhelm Schmidt, " Absorption der Sonnenstrahlung in Wasser," Met. Zeitschrift, July 1908.

TABLE II.—*Harmonic Elements of Temperatures.*

	Shade.	Cistern.		Screened Drum.
		Surface.	Bottom.	
	°	°	°	°
a_1 . . .	12·210	3·705	·680	4·732
a_2 . . .	3·909	1·994	·217	1·456
a_3 . . .	·441	·868	·100	·259
a_4 . . .	1·209	·341	·043	·110
A_1 . . .	230·15	218 97	157·55	187·92
A_2 . . .	56·82	27·21	28·92	10·35
A_3 . . .	7·92	195 03	205·30	175·55
A_4 . . .	216·92	355·08	360·00	229·08
Epoch of First Maximum.				
A_1 . . .	1440	1524	1930	1728
A_2 . . .	107	206	202	239
A_3 . . .	149	540	526	605
A_4 . . .	353	135	130	341

[*Note.*—The observations were made with thermometers graduated in Fahrenheit degrees ; the customary graduation for meteorological work in South Africa. They have been left at that chiefly because their translation into centigrade degrees would have masked the second minimum of temperature for the bottom of the cistern. The ratios between the various amplitudes above are, of course, independent of thermometer graduation.]

COLOUR AND CHEMICAL CONSTITUTION.

PART XVIII.—COLOURLESS SUBSTANCES IN H₂SO₄ (HALOCHROMY).

By JAMES MOIR.

Halochromy, or the phenomenon of the appearance of colour when certain colourless substances are dissolved in anhydrous (or nearly anhydrous) acids, is familiar to every analyst, and since I have discovered that the colours produced can be predicted from the chemical constitution, it appears to be worth while putting the method of calculation on record, in case it should be capable of practical application in toxicology, etc.

The most striking fact in connection with halochromy is that the laws are simpler than in aqueous solution, since apparently a single set of colour-factors apply to all substances, whether they are monocyclic or dicyclic. The colours are all comparatively high, viz. over $\lambda\,360$ in absorption, so that it is simplest to assume that all the substances behave as if they were *dicyclic*. Concentrated sulphuric acid is capable of combining with oxygen in any compound, in any state of combination whatever, to form an oxonium salt : consequently any substance which is unsaturated and contains at least one oxygen atom (*e.g.* triphenylcarbinol, which has one oxygen and three unsaturated benzene rings) exhibits colour in H_2SO_4 solution, which colour disappears on diluting the acid ; but it is to be noted that the bands are not sharp and strong unless the substance contains *two* groups (hapton and auxochrome). The leuco-compounds (with auxochrome alone) absorb the ultraviolet end indefinitely, and the compounds possessing a hapton but no auxochrome have a broad absorption in the blue.

These are all different from the observations in water solution, except in the case of *p*-oxybenzaldehyde and nitrosophenol.

The colours observed can be calculated as before from a parent substance by multiplying by colour-factors corresponding to the difference from the parent substance.

Table of Halochromic Colours.*

(Observed in Concentrated Sulphuric Acid.)

Name.	λ	Name.	λ
Triphenylcarbinol . . .	417	Fluorescein . . .	432
Paraoxybenzhydrol . .	460	Fluorane . . .	$\begin{cases}478\\455\end{cases}$
Paraoxybenzylalcohol . .	488		
Benzhydrol	442	Xanthone . . .	$\begin{cases}340\\405\end{cases}$
Fuchsone	454	Xanthhydrol . . .	450
Benzaurine (p–p variety) .	473	Paraoxybenzophenone .	410
Aurine	481	Phenyl-salicylic-phthalein	474
Monophenolphthalein .	488	Paraoxybenzaldehyde .	340
Phenolphthalein . .	497	Paranitrosophenol .	$\begin{cases}700\\405\\333\end{cases}$
Oxydiphenylphthalide . .	468		
Benzoylbenzoic acid .	408	Dioxybenzhydrol (p–p) .	491
Paraoxybenzoylbenzoic acid	$\begin{cases}460\\434\end{cases}$	Dimethylaminobenzaldehyde .	330
Dimethylaminofuchsone .	468	Nitrosodimethylaniline	$\begin{cases}550\\340\end{cases}$
Phenoldimethylanilinephthalein	430		

A suitable parent substance is the one already used for monocyclic substances in water solution, viz. paraoxybenzyl alcohol (see **Part XIII**, page 36).† As shown above, this has an orange colour (λ 488) in H_2SO_4, although it is colourless in all other media.

Colour-factors for Conc. H_2SO_4 Solution.

Phenyl/H substitution .	$=0.96$	C_6H_4OH/C_6H_5 . . .	$=1.06$
Phthalein or $C_6H_4CO_2H/H$	$=1.01$	Bridge-oxygen . . .	$=0.87$
Oxyphenyl or HOC_6H_4/H '.	$=1.02$	Hapton-oxidation	$=0.89$ and 0.70

Applying these we get the following results :—

Benzyl alcohol : from parent oxybenzyl alcohol : calculated $488 \div 1.06 = \lambda$ 460. This agrees roughly with observation, but the product with conc. H_2SO_4 is probably a polymer.

Benzhydrol : foregoing $\times 0.96$ $= \lambda$ 442 calculated (see Table).

Triphenylcarbinol : $\times 0.96$ again $= \lambda$ 424   ,,   ,,

* For earlier observations see page 13 of Part I.

† This was predicted to have λ 290 in alkaline water. I have now observed it and find λ 293.

Oxybenzhydrol : 488×0.96 $= \lambda\ 468$ calculated (see Table).
Fuchsone : $488 \times (0.96)^2$ $= \lambda\ 459$,, ,,
Dioxybenzhydrol : oxybenzhydrol $\times 1.06 = \lambda\ 495$,, ,,
Benzaurine : foregoing $\times 0.96$ $= \lambda\ 475$,, ,,
Aurine : should be same : looped orbit (J.C.S., 1921, 1664).
Monophenolphthalein : parent substance $\times 1.01 = \lambda\ 493$ calculated.
Phenolphthalein : foregoing $\times 1.02$ $= \lambda\ 503$,,
Oxydiphenylphthalide : phenolphthalein $\div 1.06 = \lambda\ 475$,,
Benzophenone : benzhydrol $\times 0.89$ $= \lambda\ 394$,,
Benzoylbenzoic acid : foregoing $\times 1.01 \div 0.96 = \lambda\ 415$,,
Oxybenzoylbenzoic acid : foregoing $\times 1.06 = \lambda\ 440$,,

Note.—The higher band at $\lambda\ 460$ observed is probably due to a double combination with H_2SO_4 to form a doubly-oxonium salt.

Fluorescein : phenolphthalein $\times$ bridge-oxygen $= \lambda\ 437$ calculated.
Xanthone : benzophenone $\times$,, $= \lambda\ 344$,,
Xanthhydrol : benzhydrol $\times$,, $= \lambda\ 384$,,
Fluorane : foregoing $\times 0.96$ $= \lambda\ 370$,, (Disagrees).
Oxybenzophenone : benzophenone $\times 1.06$ $= \lambda\ 417$,,

The dimethylamino-group appears to be inert in H_2SO_4.

The reason for the highness of the halochromic colours appears to be a larger orbit owing to the electron having to go *round* the *unionised* oxonium-sulphate group.

Paraoxybenzylalcohol, $\lambda\ 293$ in water, has the orbit : $O'\cdot C_6H_4 \cdot CH_2O'$,

whilst in H_2SO_4 it becomes quinomethane oxonium sulphate,

$$CH_2 : \bighexagon : O\cdot SO_4H \quad \text{or} \quad SO_4H\cdot CH_2\cdot C_6H_4\cdot OSO_3H,$$
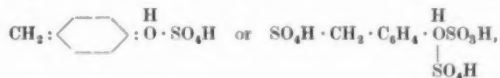
with a colour 60 per cent. higher.

THE SERUM CONSTITUENTS RESPONSIBLE FOR THE SACHS-GEORGI AND WASSERMANN REACTIONS.

By T. J. Mackie, M.D., D.P.H.

(From the Department of Bacteriology, University of Cape Town.)

Since the Sachs-Georgi or flocculation reaction was first described as a practical serum test for syphilis, the relationship of this reaction to the Wassermann or complement-deviation test has been a subject of some interest to serological workers. It has been supposed that the precipitation or flocculation effect and the complement-deviation reaction are dependent on the same underlying interaction between the syphilitic serum and the lipoid antigen. Undoubtedly the two reactions tend to correspond closely when estimated quantitatively with different sera. On the other hand, this correspondence is by no means constant.

In analysing serological reactions, the investigation of the different serum constituents has generally yielded information of some significance. This method has been extensively applied in the study of serum-complement (Liefman (1), Sachs and Altmann (2), Browning and Mackie (3), and others).

With a view to ascertaining whether the flocculation reaction was a function of the same serum constituents as the Wassermann effect, a number of sera reacting positively in both tests were fractioned by the methods adopted in the analysis of complement, and the flocculating and the complement-deviating effect of the fractions were quantitatively compared with those of the native serum.

The Wassermann technique employed was that described by Mackie and Rowland (4) ; the Sachs-Georgi reactions were carried out according to the method described by Mackie (5).

When serum is diluted with 9 volumes of ice-cold distilled water and carbon dioxide gas is then passed through the mixture, a precipitate is obtained which represents the euglobulin and portion of the pseudo-globulin of the serum (Browning and Mackie (6)) ; the albumin and the remainder of the pseudo-globulin remain in solution. In this way two serum fractions can be obtained which, as regards complement-containing serum represent separate components of complement—the so-called " mid-piece " (carbonic-

acid-insoluble) and " end-piece " (carbonic-acid-soluble). These fractions
have been designated also the " globulin " and the " albumin " fractions,
though the former contains only a portion of the globulin and the latter
a considerable proportion of globulin as well as albumin.

Syphilitic sera were " split " by the carbon dioxide method of Liefman,
and it was found that the activity of the serum in the flocculation reaction
depended almost entirely on the carbonic-acid-soluble fraction (Table I),
as has been shown also by Sahlman (7).

<div align="center">

TABLE I.—*Blood withdrawn 7/9/22.*

SACHS-GEORGI REACTION.

</div>

0·4 c.c. varying dilutions of serum or serum fractions + 0·2 c.c. cholesterinised heart extract antigen dil.
1 in 6 with normal saline.

		Serum Dilutions.						
		1 in 2.	1 in 4.	1 in 8.	1 in 10.	1 in 16.	1 in 32.	1 in 64.
8/9/22.	Unheated serum	+ + + +	+ +	+ +	.	—	—	—
	Serum 55° C.	+ +	+ + + +	+ + + +	.	+ + + +	+ + +	—
11/9/22.	Unheated serum	—	—	—	.	—	—	—
	Serum 55° C.	—	+	+ +	.	+ +	+	—
11/9/22.	From heated serum :—							
	Carbonic - acid - in - soluble fraction ; precipitate dissolved in vol. of normal saline equal to 2 vols. of serum from which derived.	—	—	—	.	—	—	—
	Carbonic - acid - soluble fraction representing 1 in 10 dil. of original serum.	.	.	.	+ + + +	+ + + +	+ + +	—
	Both fractions together.	.	.	.	.	+	+	—

Number of + marks denotes degree of flocculation ; — mark signifies absence of flocculation : readings
made after twenty-four hours.

Further experiments were then carried out, in which the **carbonic-acid-**
soluble fraction was " split " into pseudo-globulin and albumin by the
ammonium sulphate method (according to the technique utilised by Browning
and Mackie in the analysis of complement). In this way three serum
fractions were obtained : (1) carbonic-acid-insoluble globulin, (2) carbonic-
acid-soluble pseudo-globulin, and (3) albumin. It was found that the
flocculating effect of the serum was almost entirely a function of the carbonic-
acid-soluble pseudo-globulin, and that the carbonic-acid-insoluble fraction,
as previously noted, was inactive and inhibitory. The albumin was in-
active but non-inhibitory. (Table IIA shows the results of one of these
experiments.)

TABLE IIA.—*Blood withdrawn 14/9/22.*

SACHS-GEORGI REACTION.

0·4 c.c. varying dilutions of serum or serum fractions + 0·2 c.c. of cholesterinised heart extract antigen dil. 1 in 6 with normal saline.

	Serum Dilutions.						
	1 in 2.	1 in 4.	1 in 8.	1 in 10.	1 in 16.	1 in 32.	1 in 64.
15/9/22. Unheated serum	+ +	+ +	+ +	.	+ + +	+ +	+
Serum 55° C.	+ + + +	+ + + +	+ + + +	.	+ + +	+ +	+
18/9/22. Unheated serum	+ +	+ +	+ +	.	+ +	–	–
Serum 55° C.	–	+ +	+ + + +	.	+ + +	+ +	–
18/9/22. Carbonic-acid-insoluble fraction dissolved in vol. of normal saline equal to vol. of serum from which derived.	–	–	–	.	–	–	–
" Carbonic-acid-soluble fraction representing 1 in 10 dil. of original serum.	.	[1 : 16 dilution 1·6 c.c. 0·8 c.c. 0·2 c.c. antigen		+ + + +	+ + +	+ +	–
" Both these fractions together.	.	+ + + + + + + +]		.	+	–	–
19/9/22. Carbonic-acid-soluble pseudo-globulin representing 1 in 8 dil. of original serum.	[1·6 c.c. 0·2 c.c. antigen + + + +	0·8 c.c. + + + +]	+ + + +	.	+ + +	+ +	–
" Albumin representing 1 in 16 dil. of original serum.	.	[1·6 c.c. 0·2 c.c. antigen –	0·8 c.c. –]	.	–		–
" Carbonic-acid-soluble pseudo-globulin 1 in 8 + Albumin 1 in 16.	.	0·8 c.c. 1·6 c.c.	0·4 c.c. 0·8 c.c.	.	0·2 c.c. 0·4 c.c. saline sol.	0·1 c.c. 0·2 c.c. 0·1 c.c.	0·05 c.c. 0·1 c.c. 0·25 c.c.
	+ + + +	+ + +		0·2 c.c. antigen + + +	+ +	–	
19/9/22. Carbonic-acid-soluble pseudo-globulin 1 in 8. + Carbonic-acid-insoluble globulin 1 in 2.		0·8 c.c. 0·2 c.c.	0·4 c.c. 0·1 c.c.	.	0·2 c.c. 0·05 c.c.	0·1 c.c. 0·025 c.c.	0·05 c.c. 0·0125 c.c.
					Made up to 0·4 c.c. with saline sol.		
	–	–		0·2 c.c. antigen –	–	–	

These three fractions were also studied as regards their Wassermann effects, and it was noted that the most active constituent was the carbonic-acid-insoluble globulin, though the carbonic-acid-soluble pseudo-globulin also exhibited a weak reaction : the full effect of the serum was elicited by

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combining the two globulin components; the albumin was inactive (Table IIB). Kapsenberg (8) has also shown recently by the ammonium

TABLE IIB.—*Serum of Table* IIA.

WASSERMANN REACTIONS.

Original serum	deviates 14 doses of complement			
Carbonic-acid-insoluble globulin	,, 10	,,	,,	
Carbonic-acid-soluble fraction	,, 4	,,	,,	
Carbonic-acid-soluble pseudo-globulin	,, 4	,,	,,	in Wassermann reaction.
Albumin	,, 0	,,	,,	
Carbonic-acid-insoluble globulin + Carbonic-acid-soluble pseudo-globulin	,, 14	,,	,,	

Amounts of fractions used all strictly comparable with one another and with the amount of serum used in the test.

sulphate method that the Wassermann reaction depends entirely on the globulin of the serum.

Thus, on analysing sera in this way, it has been shown that the fraction mainly responsible for the Wassermann reaction is inactive in the flocculation test and even inhibitory to the active constituent, which is only weakly effective in the complement-deviation test.

By this method of analysis the two reactions appear to be independent and complement-deviation can hardly be regarded as dependent on the formation of a precipitate in the mixture of syphilitic serum and lipoid antigen, for a marked Wassermann effect occurs with a serum fraction which is inactive in the precipitation test and the full Sachs-Georgi reaction is elicited with a fraction that is only slightly active in the Wassermann test.

Heating of the serum to 55° C. for half an hour is an important factor in intensifying the flocculation effect; on the other hand, in some instances, heated serum may be less active than fresh serum (Table III). Heating acts apparently by diminishing the inhibitory effect of the inactive globulins (Table IV).

TABLE III.

SACHS-GEORGI REACTION.

0·4 c.c. varying serum dilutions + 0·2 c.c antigen (*v.* previous tables)

Serum.	1 in 2.	1 in 4.	1 in 8.	1 in 16.	1 in 32.	1 in 64.
(1) Unheated .	−	—	+	+ + +	+ + +	—
55° C.	+ + + +	+ + +	+ + + +	+ + +	+ + +	—
(2) Unheated .	+ + + +	+ + +	+ +	—	—	—
55° C.	+ +	+ + + +	+ + + +	+ + + +	+ + +	—
(3) Unheated .	+ +	+ + + +	+	—	—	—
55° C.	+ + + +	+ + + +	+ + +	+ +	—	—
(4) Unheated .	−	+ + +	+ +	+ +	—	—
55° C.	+ + +	+ + +	+ +	+ +	—	—
(5) Unheated .	+ + + +	+ + + +	+ + + +	+ + +	+ + +	+
55° C.	+ + +	+ +	+ +	+ + +	+ + +	+
(6) Unheated .	+ + +	+	—	—	—	—
55° C.	+ + + +	+ + + +	+ + +	+ +	—	—
(7) Unheated .	+ + + +	+ + + +	+ + +	+ +	—	—
55° C.	+ +	+ +	+ + +	+ +	—	—
(8) Unheated .	+ + + +	+ + + +	+ + +	+ +	—	—
55° C.	+	+ +	+ +	+	—	—

Readings after twenty-four hours.

TABLE IV.

SACHS-GEORGI REACTION.

0·4 c.c. varying dilutions of serum or serum-fractions + 0·2 c.c. antigen dilution (*v.* previous tables).

Serum.	Serum Dilutions.						
	1 in 2.	1 in 4.	1 in 8.	1 in 10.	1 in 16.	1 in 32.	1 in 64.
Unheated .	—	—	+	.	+ + +	+ + +	−−
55° C.	+ + + +	+ + + +	+ + + +	.	+ + + +	+ + +	—
From unheated serum—							
Carbonic-acid-soluble fraction, 1 in 10	.	.	.	+ + + +	+ + + +	+ + +	+ +
Carbonic - acid - insoluble fraction, 1 in 2	+	—	—	—	—	—	—
Both fractions together .	.	.	.	.	+ +	+ +	—
From heated serum—							
Carbonic-acid-soluble fraction, 1 in 10	.	.	.	+ + + +	+ + + +	+ + +	+
Carbonic - acid - insoluble fraction, 1 in 2	+	+	—	—	—	—	—
Both fractions together .	.	.	.	.	+ + + +	+ + +	+

Readings after twenty-four hours.

It has been noted also that the maximum Sachs-Georgi effect may only be obtained with sera from recently withdrawn specimens of blood. Sera kept for a few days tend to show a weaker reaction and marked zone effects (Tables V, I, and IIA). This is apparently due to an increased inhibitory effect on the part of the inactive globulin fraction as shown in Table I ;

thus the carbonic-acid-soluble fraction is more active by itself than the pure serum, four days after withdrawal of the blood, and represents the original activity of the serum from the fresh specimen.

To elicit optimum results therefore in the Sachs-Georgi reaction, serum should be used for the test as soon as possible after removal of the blood, and both heated and unheated specimens should be tested. In an older specimen, the maximum effect may be obtained by fractioning with carbon dioxide and testing the carbonic-acid-soluble fraction.

This study of the serum fractions in the Sachs-Georgi reaction has elicited information regarding the mechanism of the reaction which is of considerable theoretic and practical interest.

The inhibitory effect of one serum fraction to the action of another has already been emphasised in reference to other serum reactions (Mackie (9)), and the practical significance of this effect is well exemplified in these experiments.

TABLE V.

SACHS-GEORGI REACTION.

0·4 c.c. varying dilutions of serum + 0·2 c.c. antigen dilution.

				1 in 2.	1 in 4.	1 in 8.	1 in 16.	1 in 32.	1 in 64.
Serum (1).									
After 1 day—Unheated	.	.	.	+ + + +	+ +	+ +	—	—	—
55° C.	.	.	.	+ +	+ + + +	+ + + +	+ + + +	—	—
After 4 days—Unheated	.	.	.	—	—	—	—	—	—
55° C.	.	.	.	—	+	+ +	+ +	+	—
Serum (2).									
After 1 day—Unheated	.	.	.	+ +	+ +	+ +	+ + +	+ + +	+
55° C.	.	.	.	+ + + +	+ + + +	+ + + +	+ + +	+ + +	+ + +
After 5 days—Unheated	.	.	.	+ +	+ +	+ +	+ +	—	—
55° C.	.	.	.	—	+ +	+ + + +	+ + +	+ +	+

Readings after twenty-four hours.

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NOTE ON A PROPERTY OF BIGRADIENT ARRAYS CONNECTED WITH SYLVESTER'S DIALYTIC ELIMINANT.

By Sir Thomas Muir, F.R.S.

1. The property in all its generality may be enunciated thus :—

If the dialytic eliminant of

$$\left.\begin{array}{l} a_0x^m + a_1x^{m-1} + \ \ldots \ + a_m = 0 \\ b_0x^n + b_1x^{n-1} + \ \ldots \ + b_n = 0 \end{array}\right\},$$

written in the form

$$\begin{vmatrix} a_0 & & \ldots \ldots & b_0 & & \ldots \ldots \\ a_1 & a_0 & \ldots \ldots & b_1 & b_0 & \ldots \ldots \\ a_2 & a_1 & \ldots \ldots & b_2 & b_1 & \ldots \ldots \\ a_3 & a_2 & \ldots \ldots & b_3 & b_2 & \ldots \ldots \\ \cdot & \cdot & \ldots \ldots & \cdot & \cdot & \ldots \ldots \end{vmatrix},$$

have its array augmented by so annexing r columns of a's and r columns of b's as to continue the original plan of formation, the number of rows being thus m+n+r *and the number of columns* m+n+2r, *then all the primary minors of the resulting array (that is to say, all the determinants got from it by deleting any r columns) are divisible by the original eliminant.*

Thus if we take the case where $m=3$ and $n=2$ and where consequently the eliminant is

$$\begin{vmatrix} a_0 & \cdot & b_0 & \cdot & \cdot \\ a_1 & a_0 & b_1 & b_0 & \cdot \\ a_2 & a_1 & b_2 & b_1 & b_0 \\ a_3 & a_2 & \cdot & b_2 & b_1 \\ \cdot & a_3 & \cdot & \cdot & b_2 \end{vmatrix}$$

the theorem asserts that such arrays as

$$\begin{Vmatrix} a_0 & \cdot & \cdot & b_0 & \cdot & \cdot & \cdot \\ a_1 & a_0 & \cdot & b_1 & b_0 & \cdot & \cdot \\ a_2 & a_1 & a_0 & b_2 & b_1 & b_0 & \cdot \\ a_3 & a_2 & a_1 & \cdot & b_2 & b_1 & b_0 \\ \cdot & a_3 & a_2 & \cdot & \cdot & b_2 & b_1 \\ \cdot & \cdot & a_3 & \cdot & \cdot & \cdot & b_2 \end{Vmatrix}, \quad \begin{Vmatrix} a_0 & \cdot & \cdot & \cdot & b_0 & \cdot & \cdot & \cdot & \cdot \\ a_1 & a_0 & \cdot & \cdot & b_1 & b_0 & \cdot & \cdot & \cdot \\ a_2 & a_1 & a_0 & \cdot & b_2 & b_1 & b_0 & \cdot & \cdot \\ a_3 & a_2 & a_1 & a_0 & \cdot & b_2 & b_1 & b_0 & \cdot \\ \cdot & a_3 & a_2 & a_1 & \cdot & \cdot & b_2 & b_1 & b_0 \\ \cdot & \cdot & a_3 & a_2 & \cdot & \cdot & \cdot & b_2 & b_1 \\ \cdot & \cdot & \cdot & a_3 & \cdot & \cdot & \cdot & \cdot & b_2 \end{Vmatrix}, \ldots$$

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the one 6-by-7 and the other 7-by-9, have every one of their primary minors divisible by the said eliminant.

2. Our mode of proof, which is only fully applicable to the important case where r is 1, is based on a well-known property of resultants, namely, that the resultant of f and gh is the product of the resultants of f, g and f, h, where f, g, h are functions of the type already spoken of. Taking a very simple case, merely for ease in writing,

$$
\begin{aligned}
f &= a_0 x^2 + a_1 x + a_2, \\
g &= b_0 x^2 + b_1 x + b_2, \\
h &= c_0 x + c_1,
\end{aligned}
$$

we have, to start with, the resultant of f, gh

$$
= \begin{vmatrix}
a_0 & \cdot & \cdot & b_0 c_0 & \cdot \\
a_1 & a_0 & \cdot & b_1 c_0 + b_0 c_1 & b_0 c_0 \\
a_2 & a_1 & a_0 & b_2 c_0 + b_1 c_1 & b_1 c_0 + b_0 c_1 \\
\cdot & a_2 & a_1 & b_2 c_1 & b_2 c_0 + b_1 c_1 \\
\cdot & \cdot & a_2 & \cdot & b_2 c_1
\end{vmatrix}
$$

This bigradient, however, is readily seen to be expressible as the row-by-row product of the two 5-by-6 arrays

$$
\left\|
\begin{array}{cccccc}
1 & \cdot & \cdot & \cdot & \cdot & \cdot \\
\cdot & 1 & \cdot & \cdot & \cdot & \cdot \\
\cdot & \cdot & 1 & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & c_0 & c_1 & \cdot \\
\cdot & \cdot & \cdot & \cdot & c_0 & c_1
\end{array}
\right\| , \quad
\left\|
\begin{array}{cccccc}
a_0 & \cdot & \cdot & b_0 & \cdot & \cdot \\
a_1 & a_0 & \cdot & b_1 & b_0 & \cdot \\
a_2 & a_1 & a_0 & b_2 & b_1 & b_0 \\
\cdot & a_2 & a_1 & \cdot & b_2 & b_1 \\
\cdot & \cdot & a_2 & \cdot & \cdot & b_2
\end{array}
\right\|
$$

and must therefore be equal to the sum of six products, each of which is got by multiplying a primary minor of the first array by the corresponding primary minor of the second. Calling the latter minors M_1, M_2, . . . , M_6 and noting that the former are

$$
, \ 0, \ 0, \ 0, \ c_1^2, \ c_1 c_0, \ c_0^2,
$$

we thus obtain our result in the form

$$
c_1^2 M_4 + c_1 c_0 M_5 + c_0^2 M_6.
$$

Next we bring forward the second member of the auxiliary theorem—the product of the resultants of f, g and f, h—namely,

$$
\begin{vmatrix}
a_0 & \cdot & b_0 & \cdot \\
a_1 & a_0 & b_1 & b_0 \\
a_2 & a_1 & b_2 & b_1 \\
\cdot & a_2 & \cdot & b_2
\end{vmatrix}
\cdot
\begin{vmatrix}
a_0 & c_0 & \cdot \\
a_1 & c_1 & c_0 \\
a_2 & \cdot & c_1
\end{vmatrix}
$$

or, say, $\qquad\qquad R_{22} \cdot (a_0c_1{}^2 + a_2c_0{}^2 - a_1c_0c_1),$

and we at once see, on making comparison, that

$$M_4, \; M_5, \; M_6 \; = \; a_0R_{22}, \; -a_1R_{22}, \quad a_2R_{22}\,;$$

and we observe further that we might as readily have got

$$M_1, \; M_2, \; M_3 \; = \; b_0R_{22}, \; -b_1R_{22}, \quad b_2R_{22},$$

had we made an interchange of f and g.

Not only, therefore, have we learned that all the M's have R_{22} for a factor, but we have come to know the cofactors as well. By using a short and self-explanatory notation for bigradients, the result may be put in a quite concise form, namely, *All the primary minors of the array*

$$\begin{Vmatrix} (a_0, \, a_1, \, \ldots , \, a_m)_{n+1} \\ (b_0, \, b_1, \, \ldots , \, b_n)_{m+1} \end{Vmatrix} \quad \textit{are divisible by} \quad \begin{vmatrix} (a_0, \, a_1, \, \ldots , \, a_m)_n \\ (b_0, \, b_1, \, \ldots , \, b_n)_m \end{vmatrix}$$

the cofactors being $(-1)^{m-1}b_0, \; (-1)^{m-2}b_1, \; \ldots \ldots , \; a_0, \; -a_1, \; a_2, \; \ldots$

3. When the cofactors are of the second degree, which happens when the r of our theorem is greater than 1, the finding of their values is not at all so simple, the above method being only applicable to certain groups of them. Thus, taking the case where r is 2 and proceeding as before, we have the product of the resultants of

$$\left. \begin{array}{c} a_0x^2+a_1x+a_2=0 \\ b_0x^2+b_1x+b_2=0 \end{array} \right\} \; \text{ and } \; \left\{ \begin{array}{c} a_0x^2+a_1x+a_2=0 \\ c_0x^2+c_1x+c_2=0 \,; \end{array} \right.$$

that is, $\qquad\qquad R_{22} \cdot \begin{vmatrix} a_0 & \cdot & c_0 & \cdot \\ a_1 & a_0 & c_1 & c_0 \\ a_2 & a_1 & c_2 & c_1 \\ \cdot & a_2 & \cdot & c_2 \end{vmatrix}$

= resultant of $a_0x^2+a_1x+a_2$ and $(b_0x^2+b_1x+b_2)(c_0x^2+c_1x+c_2)$

$$= \begin{vmatrix} a_0 & a_1 & a_2 & \cdot & \cdot & \cdot \\ \cdot & a_0 & a_1 & a_2 & \cdot & \cdot \\ \cdot & \cdot & a_0 & a_1 & a_2 & \cdot \\ \cdot & \cdot & \cdot & a_0 & a_1 & a_2 \\ b_0c_0 & b_0c_1+b_1c_0 & b_0c_2+b_1c_1+b_2c_0 & b_1c_2+b_2c_1 & b_2c_2 & \cdot \\ \cdot & b_0c_0 & b_0c_1+b_1c_0 & b_0c_2+b_1c_1+b_2c_0 & b_1c_2+b_2c_1 & b_2c_2 \end{vmatrix}$$

$$= \begin{Vmatrix} 1 & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & 1 & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & 1 & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & 1 & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & c_0 & c_1 & c_2 & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & c_0 & c_1 & c_2 \end{Vmatrix} \cdot \begin{Vmatrix} a_0 & \cdot & \cdot & b_0 & \cdot & \cdot & \cdot \\ a_1 & a_0 & \cdot & b_1 & b_0 & \cdot & \cdot \\ a_2 & a_1 & a_0 & b_2 & b_1 & b_0 & \cdot \\ \cdot & a_2 & a_1 & a_0 & \cdot & b_2 & b_1 & b_0 \\ \cdot & \cdot & a_2 & a_1 & \cdot & \cdot & b_2 & b_1 \\ \cdot & \cdot & \cdot & a_2 & \cdot & \cdot & \cdot & b_2 \end{Vmatrix}$$

$$= c_2{}^2 \, \boxed{56} + c_1c_2 \, \boxed{57} + (c_1{}^2 - c_0c_2) \, \boxed{58} + c_0c_2 \, \boxed{67} + c_0c_1 \, \boxed{68} + c_0{}^2 \, \boxed{78}$$

where $\lfloor hk \rfloor$ is that minor of the right-hand 6-by-8 array which is got by deleting the hth and k^{th} columns; and, on equating cofactors of like products of the c's, we obtain

$$\lfloor 56 \rfloor, \quad \lfloor 57 \rfloor, \quad \lfloor 58 \rfloor, \quad \lfloor 67 \rfloor, \quad \lfloor 68 \rfloor, \quad \lfloor 78 \rfloor$$

$$= \text{R}_{22}(a_0{}^2, \quad -a_0 a_1, \quad a_0 a_2, \quad a_1{}^2 - a_0 a_2, \quad -a_1 a_2, \quad a_2{}^2),$$

and thence by implication

$$\lfloor 12 \rfloor, \quad \lfloor 13 \rfloor, \quad \lfloor 14 \rfloor, \quad \lfloor 23 \rfloor, \quad \lfloor 24 \rfloor, \quad \lfloor 34 \rfloor$$

$$= \text{R}_{22}(b_0{}^2, \quad -b_0 b_1, \quad b_0 b_2, \quad b_1{}^2 - b_0 b_2, \quad -b_1 b_2, \quad b_2{}^2).$$

It will thus be noted that, whereas in the case of r being equal to 1 *all* the primary minors of the array were at once shown to be divisible by R_{22}, in this case only 12 out of a total of 28 are accounted for. Fortunately a large number of the others are readily dealt with by using the results of the previous case. There nevertheless remain two forms that require special treatment, namely,

$$\begin{vmatrix} a_0 & . & b_0 & . & . & . \\ a_1 & . & b_1 & b_0 & . & . \\ a_2 & . & b_2 & b_1 & b_0 & . \\ . & a_0 & . & b_2 & b_1 & b_0 \\ . & a_1 & . & . & b_2 & b_1 \\ . & a_2 & . & . & . & b_2 \end{vmatrix} \quad \text{and} \quad \begin{vmatrix} a_0 & . & . & b_0 & . & . \\ a_1 & . & . & b_1 & b_0 & . \\ a_2 & a_0 & . & b_2 & b_1 & . \\ . & a_1 & a_0 & . & b_2 & b_0 \\ . & a_2 & a_1 & . & . & b_1 \\ . & . & a_2 & . & . & b_2 \end{vmatrix}$$

which are equal to

$$(b_1{}^2 - b_0 b_2)\text{R}_{22} \quad \text{and} \quad (a_2 b_0 - a_1 b_1)\text{R}_{22}$$

respectively.

In view of the facts here brought out, a proof quite independent of the general theory of resultants would be of considerable value.

4. It is important to note that the cofactors in the immediately preceding paragraph are all 2-line minors of R_{22}, and that, further, every 2-line minor of R_{22} with the single exception of $\lfloor a_0 b_2 \rfloor$ is found among the cofactors.

RONDEBOSCH, SOUTH AFRICA,
    2nd December 1922.

ON SOME NEW SOUTH AFRICAN PARASITIC NEMATODES.

By Dr. H. O. MONNIG,

Department of Veterinary Research, Onderstepoort, Pretoria.

(Communicated by Sir ARNOLD THEILER, K.C.M.G., D.Sc.)

(With fourteen Text-figures.)

In the following pages is offered a description of some new parasitic Nematodes which were found in a large collection of Helminths collected in South Africa by Sir Arnold Theiler and presented to Professor Dr. O. Fuhrmann at the University of Neuchâtel for investigation. The author had the opportunity, through the courtesy of Professor Fuhrmann, to examine the Nematodes of this collection, and a complete report upon this work is to be published in the near future.

For reasons to be set forth in the announced publication, the name of *Strongylus* (*Deletrocephalus*) *brachylaimus* von Linstow, 1901, syn. *Kiluluma brachylaima* Skrj., 1916, has been changed into *Theileriana brachylaima*, and I have the honour to dedicate this new genus to Sir Arnold Theiler, to whose initiative this investigation owes its origin. Also *Filaria subcutanea* von Linstow, 1901, has been renamed *Filaria subdermata*.

Superfamily ASCAROIDEA Railliet and Henry, 1915.

Family ASCARIDAE Cobbold, 1864.

Subfamily ANISAKINAE Railliet and Henry, 1912 ; emend. Baylis, 1920.

Genus *Contracaecum* Railliet and Henry, 1912.

Syn. *Kathleena* Leiper and Atkinson, 1914.

Diagnosis.—Anisakinae : Oesophagus with reduced posterior ventriculus giving off a solid posteriorly directed appendix. An intestinal caecum is present. Interlabia present, usually very well developed. Dentigerous ridges absent.

Type-species—*Contracaecum spiculigerum* Rud., 1809.

Contracaecum praestriatum n. sp.

White worms : the anterior end of the body is usually curved ventrad and tapers more than the hind end. The cuticle has very marked transverse striations, 38 μ wide, in about the anterior $\frac{1}{2}$ of the body or a little farther ; behind that point the striations suddenly become much finer and the cuticle is irregularly folded. There are three thick, broad, main lips (fig. 1) and three low interlabia ; the main lips are of equal size, and the dorsal bears two papillae while each of the others bears one, the papillae being apparently
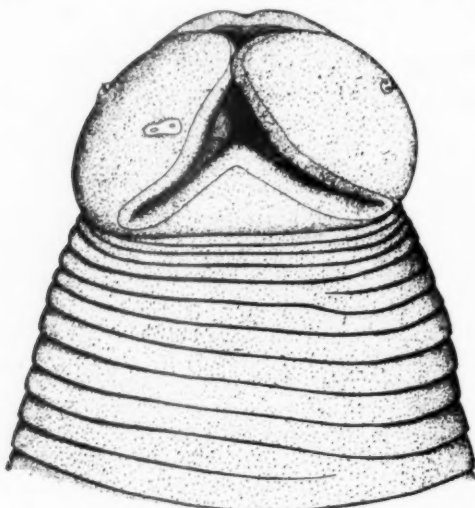
Fig. 1.—*Contracaecum praestriatum.* Lateral view of head.

all double. There is no dentigerous ridge, but the lips have strong cuticular borders. The tail is obtuse in the male, acute in the female, and has a sharp point in both sexes. The oesophagus has an anterior muscular portion and a posterior ventriculus, the whole being 4·1 mm. long ; the solid oesophageal appendix is directed backwards and is 2 mm. long, the anteriorly directed intestinal caecum is 2·3 mm. long, and the nerve-ring surrounds the oesophagus 600 μ from the anterior end, these measurements all being taken from a female specimen of 3 cm. length.

Male, 2 cm. long and 650 μ thick. The tail is 160 μ long and bears five pairs of postanal papillae, of which Nos. 1 and 2 and also 3 and 4 are situated close together and 5 is double. There are at least 18 pairs of preanal papillae situated in a ventero-lateral row on each side ; they

stand close together near the cloaca and farther apart as they extend forwards, reaching up to about 3·6 mm. in front of the anus. There are two equal, usually projecting spicules of 1·9 mm. length and a small gubernaculum measuring 120 μ. The spicules are made up of a central portion and lateral alae ; the latter narrow abruptly at the end of the central portion and then form a small, blunt continuation to this. The hinder part of the body is curved ventrad, and is provided ventrally with the usual oblique muscles (fig. 2).

Female, 3·3 cm. long and 800 μ thick. The tail is 360 μ long. The
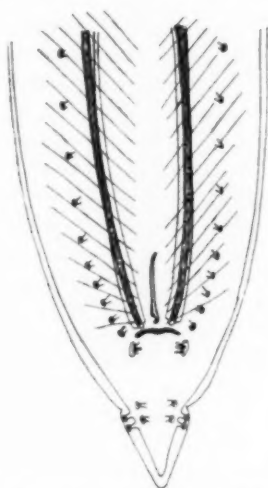
Fig. 2.—*Contracaecum praestriatum.* Hind end of male.

vulva is located at a point just behind the region where the marked cross-striations of the cuticle stop, dividing the body-length in the proportion of 5 : 12. The ovijector first runs forwards for some distance, then doubles back upon itself and gives off two backwardly directed uteri. The eggs are thin-shelled, very round, and measure 40 μ by 32 μ. Segmenting when laid.

Host.—Podiceps capensis. Transvaal.

This species resembles *Contracaecum ovale* (*Ascaris ovalis* von Linstow, 1907) from *Podiceps cristatus* in several respects. However, the measurements and proportions do not agree, and the tail is said to be rounded off at its extremity in *C. ovale.* Besides, von Linstow does not mention the very conspicuous difference of the cuticular striations in the two regions of the body, which he surely would have noticed if present in his specimens. Apparently *C. ovale* has not been described again by another author.

Superfamily OXYUROIDEA Travassos, 1920.
Family OXYURIDAE Cobbold, 1864.
Subfamily OXYURINAE Hall, 1916.
Genus *Syphaciella* n. gen.

Diagnosis.—Oxyurinae : cuticle transversely striated, inflated about the head, and forming two lateral cervical alae. Excretory pore behind level of oesophageal bulbus. Mouth surrounded by three lips ; buccal cavity absent. The oesophagus is slightly swollen posteriorly and ends in a large bulb, which is separated from the rest of the oesophagus by a distinct constriction and contains a masticatory apparatus. The intestine is swollen in front, just as wide as the bulbus. Vulva anterior, behind the excretory pore, surrounded by a prominent cuticular swelling ; cuticular ovijector long and strongly muscular ; the sphincter is spherical, and marked off from the rest of the ovijector ; the musculo-epithelial ovijector is continued as a wide reservoir, containing numerous eggs, backwards up to a short distance before the anus, where two forwardly directed uteri are given off, each enclosing a single row of eggs. The ovaries lie in the anterior part of the body. Tail of male pointed, with a mucronate tip; it bears very large lateral alae, stopping short of the tip, and there are two pairs of preanal papillae and two pairs and one unpaired postanal papilla all crowded round the cloacal aperture, and a pair of small pedunculated papillae farther back on the tail. Two subequal spicules and a gubernaculum.

Type-species—*Syphaciella capensis* n. sp.

Syphaciella capensis n. gen., n. sp.

These worms are small, white in colour, and very neatly built. The females are straight, and the males only a little curved in the posterior half of their length. The cuticle is transversely striated at intervals of 15 μ on the average. The head bears three lips which are broad behind

FIG. 3.—*Syphaciella capensis.* Lateral view of female, anterior portion.

and thus set off the head against the rest of the body ; each lip apparently bears a smaller anterior and a large posterior papilla. The oesophagus is provided with a small posterior swelling, constricted off from the spherical bulbus, which contains three chitinous teeth (fig. 3) ; the intestine begins with a swelling as wide as the bulbus, and is for the rest narrow and fairly straight. There is an inflation of the cuticle about the head, immediately posterior to which start the large lateral cervical alae. The excretory pore is situated in the middle between the oesophageal bulbus and the vulva in the female.
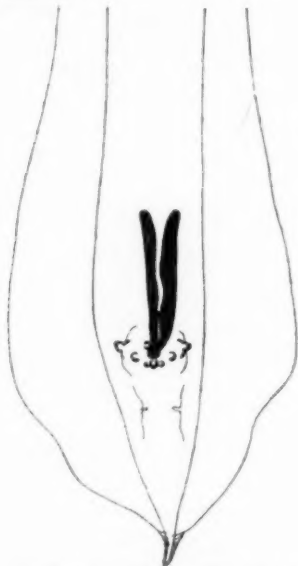
FIG. 4.—*Syphaciella capensis.*   Hind end of male.

Male, 4·04 mm. long and 200 μ thick. The oesophagus is 480 μ long ; the tail 212 μ, and is conical, with a mucronate tip (fig. 4). The caudal alae are strongly developed, 240 μ wide, 720 μ long, leaving the tip of the tail free. There are two pairs of preanal papillae, one pair situated on the anterior border of the cloaca and the other more laterally. The posterior border of the cloaca bears a median and on each side of this a smaller papilla, while more laterally is another on each side. Besides, there is a pair of thin longitudinal membranes on the ventral side of the tail supported each by a small pedunculated papilla, making a total of seven postanals. The spicules are broad, subequal, and the gubernaculum is hardly distinguishable.

Female, 5·6 mm. long and 240 μ thick. The tail is long and pointed, measuring 1 mm. The total length of the oesophagus is 580 μ, the bulbus measures 120 μ by 112 μ, the intestinal swelling is 116 μ wide and the rest of the intestine 52 μ. The cuticular head-swelling is 120 μ long, and the cervical alae pass the level of the vulva, which is 1·2 mm. from the anterior extremity. The nerve-ring surrounds the oesophagus 140 μ from the anterior end. The vulva is a large transverse slit, and is surrounded by a very prominent cuticular swelling. The vagina is 100 μ long, the cuticular ovijector 620 μ, the sphincter 100 μ; the musculo-epithelial ovijector is a wide reservoir running back to a short distance before the anus, where it gives off two forwardly directed uterine branches. The ovaries start usually behind the level of the sphincter and do not extend quite up to the oesophageal bulbus. The eggs are a little flattened on the one side, relatively large, measuring 100 μ by 40 μ.

Host.—*Pterocles bicinctus* and *Pteroclurus namaqua.* Transvaal.

<div align="center">

Superfamily SPIRUROIDEA Railliet and Henry, 1915.

Family ACUARIIDAE Seurat, 1913.

Subfamily Physalopterinae Railliet and Henry, 1912.

Genus *Leptosoma* Travassos, 1920.

</div>

Diagnosis.—Physalopterinae: male with four pairs of pedunculated caudal papillae; two very unequal spicules; female provided with four uteri.

<div align="center">

Leptosoma africana n. sp.

</div>

Body white, straight or slightly curved, tapering towards both extremities. The cuticle is inflated about the head, and surrounds the mouth in the form of a wide collar (fig. 5); it is finely striated transversely. The mouth is surrounded by two lateral lips, each bearing a small median and two large lateral papillae and also a large median " external " tooth and two lateral double teeth, the two parts of each biting upon each other. Besides, the inner surface of each lip bears a ridge of small denticles and a small trifid tooth internal to the large median tooth. There are two lateral cervical papillae, the right 0·6 mm. from the anterior end and the left 0·68 mm. The excretory pore is situated between the levels of these two papillae. The oesophagus corresponds to about ⅙ of the body-length in the female and opens into the intestine with a very distinct trilobed valve. The first 600 μ of the oesophagus is narrow and muscular, the rest wider and glandular. All specimens are provided with a dorsal papilla, sometimes two, shortly behind the middle of the body.

Male, 20 mm. long and 750 μ thick. The hind end is flexed ventrad and

provided with a wide bursa. There are four stalked papillae on each side (fig. 6), one unpaired and a pair of sessile preanal papillae, two pairs of sessile
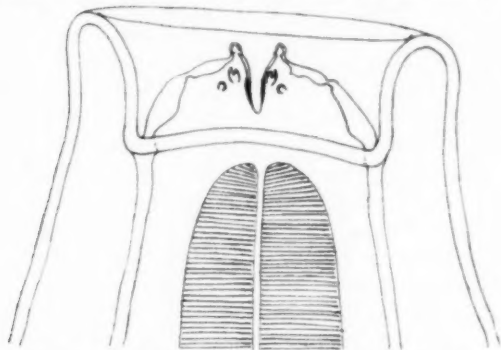
FIG. 5.—*Leptosoma africana.* Ventral view of head.
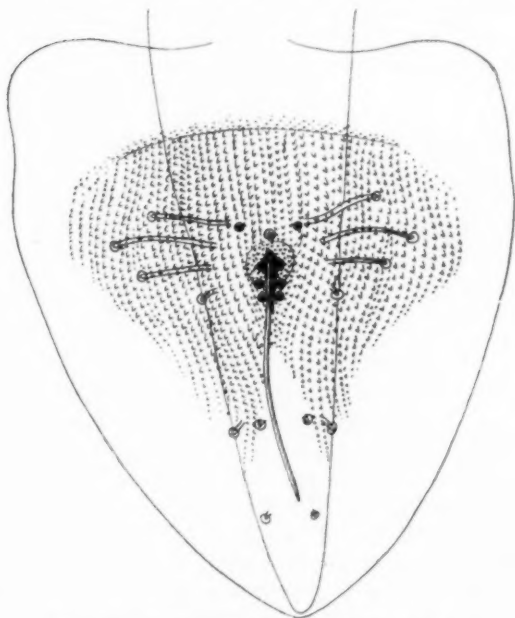
FIG. 6.—*Leptosoma africana.* Hind end of male.

papillae on the posterior margin of the cloacal aperture, two pairs of shortly stalked papillae at about the middle of the tail, and a pair of sessile papillae

¼ of the length of the tail from its end.   The ventral surface of the bursa around the cloaca is covered with conical cuticular tubercles, whose arrangement is given in the figure.   The cloacal aperture has two small lips on each side.   There are two unequal spicules, the right 500 μ and the left 3·2 mm. long, the latter projecting for some distance in a curve.

Female, 25–50 mm. long and 1–1·8 mm. thick.   The tail is pointed and straight, measuring about $\frac{1}{55}$ of the body-length.   The cuticle about the tail is often inflated.   The intestine is straight, and pressed to the dorsal side. The vulva is situated at a distance less than ½ the length of the oesophagus behind the end of the latter.   The ovijector is narrow, running directly backwards along the ventral side for 2 mm. ; it has a cuticular lining and a strong muscular coat ; the musculo-epithelial part is 2·2 mm. long, comprising anteriorly a reservoir of 1·2 mm. length ; it finally divides to form four uteri.   These all run backward, the ovaries and very distinct seminal receptacles lying in the posterior third of the body.   Eggs oval, with thick shells, measuring 85 μ by 28 μ, segmenting when laid.

Host.—Paraxerus cepapi, Otomys irroratus, Mus concha, Mus Pretoria, Arvicanthis pumilis, and *Thrynomys swindernienus.*   Intestine.   Transvaal.

This species appears to be closely related to *Physaloptera abbreviata* Rud., 1819.

<div align="center">

Superfamily STRONGYLOIDEA Weinland, 1858.

Family STRONGYLIDAE Cobbold, 1864.

Subfamily STRONGYLINAE Railliet, 1893.

Tribe *Strongyleae* Railliet and Henry, 1912.

Genus *Strongylus* Müller, 1780.

Strongylus intermedius, n. sp.

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Only a single specimen collected.   The cuticle is thick, with transverse folds 300 μ wide and fine tránsverse striations ; there are also broad, short longitudinal folds.   The specimen measures 28·2 mm. by 1 mm. and has very much the appearance, especially in the formation of the buccal capsule, of *Strongylus equinus* (fig. 7).   The buccal capsule is 900 μ deep and 420 μ wide at its oral opening.   It has exactly, as in *S. equinus,* a large dorsal tooth and two ventral teeth at its base, and the outer leaf-crown comprises about 66 laminae.   The oesophagus measures 2·6 mm. in length, without bulbus or tooth apparatus, and opens into the intestine with a distinct valve.   The excretory pore is situated ventrally before the middle of the buccal capsule. There are two long, thin spicules measuring 2·4 mm.   While the head closely resembles that of *Strongylus equinus,* the bursa resembles that of

Strongylus edentatus in no lesser degree (fig. 8), for which reason I wish to propose the name *Strongylus intermedius* for this species. The bursa has
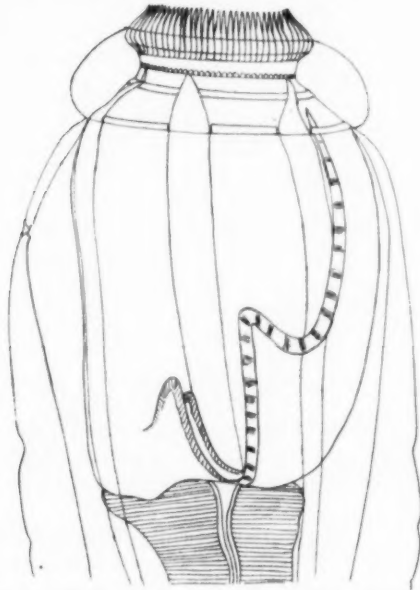
FIG. 7.—*Strongylus intermedius.* Lateral view of head.
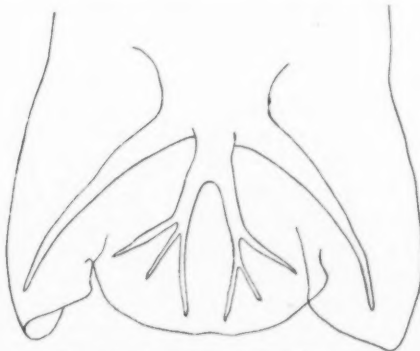
FIG. 8A.—*Strongylus intermedius.* Male bursa, dorsal view.

large lateral lobes, a small dorsal and also a smaller ventral lobe. The ventro-ventral and latero-ventral rays are thin, close together and parallel,

and do not reach the margin of the bursa. The lateral rays are mutually divergent from their bases, but do not curve. The externo-dorsal rays are well developed, and come off near the base of the common dorsal stem ;

FIG. 8B.—*Strongylus intermedius.* Male bursa, lateral view.

the latter soon bifurcates to form the two dorsal roots, each of which divides again into three thin, pointed branches, of which the inner on each side reaches nearest to the margin of the bursa. Prebursal papillae are apparently absent.

Host.—*Varanus* sp.   Zoological Gardens, Pretoria.

Family TRICHOSTRONGYLIDAE Railliet, 1915.

Subfamily HELIGMOSOMINAE Travassos, 1914.

Genus *Impalaia* n. gen.

Diagnosis.—Heligmosominae : the body is not coiled in a spiral. The cuticle has minute longitudinal striations, and is transversely striated only in the head region, where it is inflated. The head is round, and not sharply marked off from the body.' The mouth is a circular opening without lips or papillae. The vulva is located near to the anus, and there is a well-developed ovijector and a single uterus and ovary. Two thin, equal spicules and a boat-shaped gubernaculum. In the male bursa, which is hood-shaped and has no strongly marked-off dorsal lobe, the common stems of the ventral and lateral rays are short, the rays being separated near the base. The ventro-ventral and latero-ventral rays are divergent, both curving forward, and their tips are near to each other. The lateral rays run parallel for some distance but diverge distally. The dorsal trunk is thick, and has a characteristic flexure ; the externo-dorsal rays are thin, and originate from the common stem at different heights near its base ; they do not reach

the margin of the bursa ; the dorsal trunk divides into the terminal dorsal rays very far distally. The bursal rays all end in definite papillae.

Type-species—*Impalaia tuberculata* n. sp.

Impalaia * *tuberculata* n. gen., n. sp.

The worms are small, and not coiled in a spiral. The cuticle is of normal thickness, and bears minute longitudinal striations, as are met with in some Filariae, 1·5 μ apart and wavy in some places. In the anterior 86–100 μ of the body the cuticle is inflated, and the body-wall under it bears numerous irregularly arranged tubercles (fig. 9). In this inflated region and also a little behind it the cuticle is transversely striated at intervals of 2 μ. The head measures 40–45 μ in diameter. The oesophagus is 440 μ long, and is surrounded by the nerve-ring a short distance behind its middle.

Male, 7·2–7·5 mm. long by 120 μ broad just before the bursa. The fine longitudinal striations of the cuticle are continued on to the dorsal surface of the bursa along the rays. The externo-dorsal rays are thin, and the right comes off from the common dorsal stem before the left (fig. 10). The dorsal trunk is characteristically twisted, and divides to form the dorsal rays at a distance from the margin of the bursa equal to about $\frac{1}{5}$ of its length. The dorsal rays, which run almost perpendicular to their common trunk, each form an inner branch that runs directly outwards to

Fig. 9.—*Impalaia tuberculata.* Anterior portion.

the edge of the bursa, and is provided with a minute internal branch, and an external branch that curves back near its end. The postero-lateral ray runs back for some distance along the margin of the bursa, and its tip is nearer to that of the externo-dorsal ray than to that of the medio-lateral ray ; the medio-lateral runs more or less directly outwards to the margin of the bursa ; the externo-lateral curves forward. The ventro-ventral ray is smaller than the latero-ventral, and appears as a branch of the latter in the way it originates from the common stem ; they are divergent and both curve forwards, the latero-ventral reaching farther than the ventro-ventral, so that their tips are near to each other ; the extreme tips of both rays are curved backward. The spicules are thin and 600 μ long, their proximal ends are bifid, the one point being longer than the other and both curving

* The host, *Aepyceros melampus*, is commonly called *Impala* in South Africa.
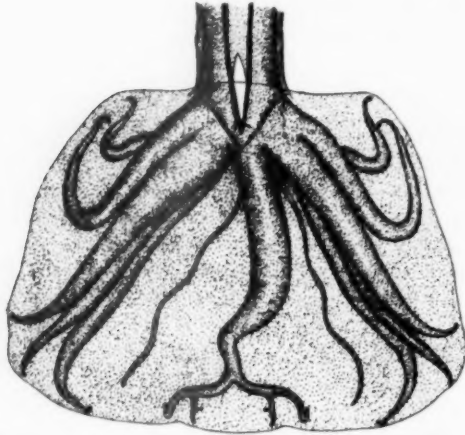
Fig. 10A.—*Impalaia tuberculata.*   Male bursa, opened out.

Fig 10B.—*Impalaia tuberculata.*   Male bursa, lateral view.

backward (fig. 11). The gubernaculum is small, boat-shaped, and coloured brightly brown.

Female, 18 mm. long by 120 μ thick. The tail is acute, pointed, with

Fig. 11.—*Impalaia tuberculata.*
Head end of spicule.
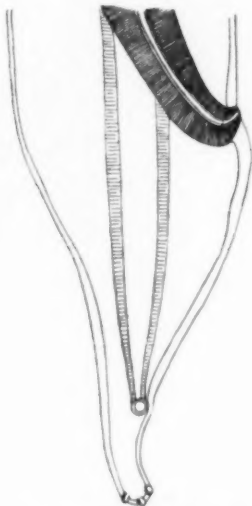
Fig. 12.—*Impalaia tuberculata.*
Hind end of female.

one terminal and two subterminal lateral papillae (fig. 12). The anus is 40 μ from the tip of the tail and the vulva 100 μ. The short vagina runs forward into an ovijector of 900 μ length, which gives off a single uterus ; the single ovary lies in the anterior $\frac{1}{4}$ of the body ; it is short and not coiled, but may be bent double. Eggs measure 60 μ by 32 μ, segmenting when laid.

Host.—Aepyceros melampus. Intestine. Transvaal.

9

SOUTH AFRICAN LARVAL TREMATODES AND THEIR INTERMEDIARY HOSTS.

By F. G. CAWSTON, M.D. Cantab.,

First Streatfeild Research Scholar.

An examination of ten thousand fresh-water molluscs from rivers along the East Coast from Port Elizabeth to Lourenço Marques reveals the presence of at least thirty-four distinct species, a few of which are bivalves. The majority of fluke-infested examples have been obtained from the surroundings of towns or in places where cattle graze. Several new localities have been determined for the intermediary hosts of Schistosoma and Fasciolae, as well as for less common trematodes. Various species of molluscs have been shown to act as intermediary hosts for the same trematode worm, and the same species has been shown to harbour several distinct parasites, more than one variety of trematode being represented in the same individual mollusc.

At least seven distinct *Isidorae* have been collected and the variability of this group well shown. In regard to those shells I posted him from Potchefstroom, Mr. Henry C. Burnup of the Natal Museum, who has kindly identified the various species for me, writes : " On reference to Jickeli's Fauna N.-.O. Afr., I have no hesitation in identifying your shells as *Isidora schackoi* Jick. A tentative identification is all that can possibly be attempted at present, owing to the confusion that exists in the literature on the subject. In the near future, however, it is hoped that ' definite determination ' may be effected."

Some *Physopses* from Bellair and Isipingo are remarkably high in the spire.

Corbicula radiata is common amongst the stones of the bed of the Mooi river at Potchefstroom. The species is well preserved, and many examples are larger than the largest measurements given by Jickeli. Even the largest *Uniones* from this river show a perfect state of the umbones with the zig-zag sculpture of early growth intact to the very tips of the beaks. The remarkable preservation of these molluscs may be due to the large amount of lime in the Mooi river at Potchefstroom. *Planorbis gibbonsi*

Nelson from the same locality was similarly well grown, *i.e.* without varices showing halys in its growth.   The species had not previously been reported from the Transvaal, though it is known from Zanzibar and Central Africa.

I procured a few examples of *Limnaea truncatula* Drap. from a pool along the course of the Mooi river and in the Loop spruit at Potchefstroom.   At one time this rare mollusc was supposed to be responsible for Fasciola infestation in South Africa ; but no cercariae have ever been demonstrated in South African examples.   The only other South African localities for the species are Umlaas river (Natal), Pretoria, and Stellenbosch.   These widely separated localities indicate pretty clearly how very imperfectly the fresh-water shells have so far been worked.

At the mouth of the Umkomaas river I found a slug which I submitted to Dr. L. Péringuey of the South African Museum.   He writes : " The slug is a species of Onchilium, a Pulmonate Shell-less Gastropod which lives between tide-marks."

The following table shows the commoner species of fresh-water mollusc that are found in the rivers visited, as well as some lagoon inhabitants which are occasionally found in quite fresh water.   It also shows which are the commoner larval trematodes of these localities.

Locality.	Molluscs.	Larval Trematodes.
Port Elizabeth—		
Baaken's Spruit	Physopsis africana Krs..	S. haematobium.
	Limnaea natalensis.	C. oblonga.
	,, ,, Krauss.	C. cawstoni.
	Burnupia gordonensis (M. & P.)	
Zaartkop River .	Limnaea natalensis Krs.	
Grahamstown—		
Kowie River .	Burnupia gordonensis (M. & P.)	
Alicedale .	Burnupia gordonensis (M. & P.)	
Umkomaas .	Cerithidea decollata L., 1⅜ ins. long.	
	Theodoxus natalensis Reeve, ⅞ inch long.	
	Theodoxus ? gagates Lam.	
	Septaria ? sp.	
	Septaria ? sp.	
Ingani . .	Cerithidea decollata L.	
	Modiola capensis Krs.	
	Assemania bifasciata Nev.	

Locality.	Molluscs.	Larval Trematodes.
Umgababa . .	Modiola capensis Krauss. Isidora sp. ? Ancylus sp. ?	
Karridene . .	Physopsis africana Krs. Limnaea natalensis Krs. Planorbis pfeifferi Krs. Septaria sp. ? Cerithidea decollata L. Cerithidea ? inaequisculpta Kobolt. Hemitapes kochii Phil.	

Illovo . . .	Planorbis pfeifferi Krs.
	Limnaea natalensis Krs.
	Isidora tropica (Krs.).
	Segmentina planodiscus (M.
	  & P.).
	Ancylus sp. ?
	Tiara tuberculata Müll.
	Modiola capensis Krs. 21 mm.
	  long. . . . .
	Septaria sp. ?
	Cerithidea decollata L.
	Sphaerium ? ferrugineum Krs.
	Succinea ? patentissima Menke.
	Succinea ? striata Krs.
		Gastronomes.

Amanzimtoti .	Physopsis africana Krs. Limnaea natalensis Krs. Isidora forskali Ehrenb. Planorbis sp. ? Ancylus sp. ? Septaria sp. ?	
Umbogintwini .	Planorbis pfeifferi Krs. Limnaea natalensis Krs. Isidora tropica (Krs.). Planorbis costulatus Krauss. Septaria sp. ? Theodoxus natalensis Reeve. Burnupia gordonensis M. & P. Bullia natalensis Krauss. Oxystele tabularis Krauss.	
Isipingo . .	Physopsis africana Krs. Limnaea natalensis Krs. Planorbis pfeifferi Krs. Segmentina planodiscus M. & P. Isidora tropica (Krs.).	

Locality.	Molluscs.	Larval Trematodes.
Isipingo—*continued.*	Isidora natalensis (Krauss). Isidora forskali Ehrenb. Ancylus sp. ? Cerithidea decollata L. Littorina scabra (Linn.) Assemania bifasciata Nev. Cassidula labrella (Desh.).	

Merebank . .	Planorbis pfeifferi Krs. 14 mm.
	   long . . . . .
	Planorbis nov. sp.
	Isidora natalensis (Krs.) (*not*
	   schackoi). . . . .
	
	Limnaea natalensis Krs.
	Segmentina planodiscus M. & P.
	Segmentina nov. sp.
		C. macrura.
		C. caudadena.
		
		C. cawstoni.
		C. cucumeriformis,
		   and a chained
		   echinostome.

Inchanga . .	Limnaea natalensis Krs. Isidora forskali Ehrenb. Ancylus sp. ?	
Clairwood . .	Isidora forskali Ehrenb. Planorbis sp. ?	
Umhlatuzana .	Physopsis africana Krs. . Limnaea natalensis Krs. Isidora forskali M. & P. Burnupia gordonensis M. & P. Planorbis anderssoni Auc.	Schistosomes.
S. Coast Junction .	Ferrissia burnupi Walker. Planorbis costulatus Krs.	

Umbilo . .	Physopsis africana Krs. ¾ inch
	   long. . . . . .
	
	Limnaea natalensis Krs. .
	Isidora tropica (Krs.).
	Isidora natalensis (Krs.) .
	Burnupia gordonensis M. & P.
	Planorbis costulatus Krs.
	Segmentina planodiscus M. & P.
	Planorbis sp. ?
	Ferrissia burnupi Walker.
		S. ? haematobium.
		S. ? bovis.
		C. secobii and redia-
		   produced schisto-
		   somes.
		C. cawstoni.
		Fasciola.

Locality.	Molluscs.	Larval Trematodes.
Sydenham, Mayville and Cator Manor	Physopsis africana Krs. 20 mm. long.	*Schistosomes—* 1. S. haematobium. 2. S. mansoni. 3. S. bovis (C. octadena). 4. C. gladii. 5. C. oculata. *Echinostomes—* 1. C. 30-acanthostoma. 2. C. constricta. 3. C. catenata. *Xiphidiocercariae—* C. cawstoni.
	Limnaea natalensis (Krs.). .	Fasciola gigantica (C. pigmentosa). *Echinostomes—* C. arcuata. *Xiphidiocercariae—* C. cawstoni. *Monostomes—* C. fulvoculata.
	·Isidora tropica (Krs.). . .	*Schistosomes* sp. ? *Amphistomes—* C. ? frondosa. *Chained echinostomes.*
	Isidora forskali Ehrenb. .	*Amphistomes—* C. ? frondosa.
	Isidora diaphana (Krs.). Planorbis pfeifferi Krs. 1·5 mm. wider than Krauss's type.	*Schistosomes* sp. ? *Echinostomes—* C. catenata.
Botanic Gardens, Durban . .	Segmentina planodiscus M. & P. Ferrissia fontanalis Walker. Ferrissia burnupi Walker. Limnaea natalensis Krs. Ferrissia burnupi Walker. Ferrissia nov. sp.	
Durban Bay .	Cerithidea decollata L. Littorina scabra. Alectrion Kraussianus Dunker. Natica marochiensis Gmelin. Volema paradisaica Reeve.	

Locality.	Molluscs.	Larval Trematodes.
Umgeni	Physopsis africana Krs.	
	Limnaea natalensis Krs .	Schistosomes, redia-produced.
		C. humilis.
		C. cucumeriformis.
	Isidora tropica Krs. and natal-ensis (Krs.) *not* schackoi.	C. cephaladena.
		C. ingracilis and chained echino-stomes.
	Isidora diaphana Krauss.	
	Isidora forskali 10 mm. long Ehrenb.	C. ? frondosa.
	Planorbis natalensis Krs.	
	Planorbis pfeifferi Krs.	
	Segmentina planodiscus M. & P. ½ mm. wider than the type.	
	Burnupia caffra (Krs.).	
	Tiara. tuberculata Müll 31 mm. long.	C. oblonga.
		C. puerilis.
	Modiola capensis Krs. 19 mm. long. . . .	Gastronomes.
	Ferrissia fontinalis Walker.	
	Planorbis costulatus Krauss.	
Umhlangana .	Physopsis africana Krs. . .	Schistosomes (some 0·875 mm. long).
		C. *pigmentosa*.
		C. *humilis*.
	Limnaea natalensis Krs. 1⅗ inch long.	C. *humilis*.
	Planorbis pfeifferi Krs.	
	Ferrissia burnupia Walker.	
	Isidora tropica (Krs.).	
	Burnupia stenochorias (M. & P.).	
	Burnupia gordonensis (M. & P.).	
	Burnupia caffra (Krs.).	
Umhlanga .	Physopsis africana Krs.	
	Limnaea natalensis Krs.	C. *cawstoni*.
	Isidora tropica (Krs.).	
	Isidora natalensis (Krs.).	
	Planorbis pfeifferi Krs.	
	Burnupia gordonensis (M. & P.).	
	Burnupia caffra (Krs.).	
Umhloti .	Limnaea natalensis Krs.	
	Planorbis pfeifferi Krs. ½ inch wide.	

Locality.	Molluscs.	Larval Trematodes.
Umhloti—*continued*.	Isidora tropica (Krs.).	
	Burnupia gordonensis (M. & P.).	
Tongaat . .	Planorbis pfeifferi Krs.	
	Isidora forskali Ehrenb. .	Schistosomes sp. ?
	Burnupia gordonensis (M. & P.).	
	Theodoxus natalensis Reeve.	
	Theodoxus sp. ?	
Nonoti . .	Isidora forskali Ehrenb. 11 mm. long.	
	Ancylus sp. ?	
Ginginhlovu . .	Limnaea natalensis Krs.	
	Ancylus sp. ?	
Amatikulu . .	Limnaea natalensis Krs. .	Fasciola and chained echinostomes.
	Isidora natalensis (Krs.) .	C. ? frondosa.
Umlalasi . .	Burnupia caffra (Krauss).	
Umsindusi—		
P. M. Burg .	Physopsis africana Krs. . .	*Schistosomes*— S. ? haematobium. C. secobii.
	·Limnaea natalensis Krs.	
	Isidora forskali Ehrenb.	
	Isidora compta M. & P.	
	Ferrissia burnupi Walker.	
Lake Chrissie, Transvaal . . .	Limnaea natalensis Krs.	Fasciola.
	Ferrissia sp. ?	
	Corbicula radiata (Parreyss).	
Pretoria . .	Limnaea natalensis Krs.	
	Ferrissia cawstoni Walker.	
Potchefstroom— Mooi river, and Loop spruit.	Limnaea natalensis Krs.	
	Limnaea truncatula Drap.	
	Planorbis pfeifferi Krs.	
	Planorbis gibbonsi (Nelson).	
	Isidora schackoi Jickeli . .	C. gladii. C. frondosa.
	Ferrissia cawstoni Walker.	
	Corbicula radiata (Parreyss).	
	Unio caffer Krauss.	
Klerksdorp— Schoonspruit.	Physopsis africana Krs.	
	Limnaea natalensis Krs.	
	Isidora sp. ?	C. arcuata.

Locality.	Molluscs.	Larval Trematodes.
Klerksdorp— Schoonspruit— *continued*.	Planorbis pfeifferi Krs. Planorbis gibbonsi Nelson. Ancylus sp. ?	
Mulder's Drift	Physopsis africana Krs. Limnaea natalensis Krs. Planorbis pfeifferi Krs. Ancylus sp. ?	S. ? haematobium.
Magaliesburg	Physopsis africana Krs. Limnaea natalensis Krs.	S. ? haematobium. C. catenata.
Rustenburg— Kloof river	Physopsis africana Krs. Limnaea natalensis Krs. Planorbis pfeifferi Krs. Ferrissia sp. ?	S. ? haematobium. C. catenata. C. catenata.
Hex river .	Limnaea natalensis and Unio caffer Krauss.	
Marico river	Physopsis africana Krs. Limnaea natalensis Krs.	
Scheerpoort .	Physopsis africana Krs. Limnaea natalensis Krs Planorbis pfeifferi Krs.	
Lourenço Marques.	Physopsis africana Krs. . Planorbis pfeifferi . Isidora forskali Ehrenb. Isidora sp. ? Lanistes ovum Peters.	Schistosomes (2 sp.), some 1 mm. long. C. oculata. Schistosomes sp. ? Schistosomes (2 sp.).

I am indebted to Dr. K. Sharpe, the Medical Inspector of Schools for Natal, for the following information that he has collected from district surgeons and other general practitioners throughout the province of Natal :—

"Along the south coast of Natal most of the smaller rivers and streams appear to be infected with Bilharzia. Amongst those that are definitely known to harbour this disease are the following : Umzimbi, Umtwalumi, Ifafa, Umzinto, Isezela, Umpambinyoni, Amahlongwe, Umquahumbi (a tributary of the Illovo river), Umlaas, Umhlatuzan, and Umbilo rivers.

"The midlands appear to be fairly free from this infection, there being only two small rivers and one stream whose waters are known to harbour Bilharzia. These are the Umsindusi river, which is a tributary of the

Umgeni, and which flows through the Maritzburg district.   The Dorp spruit, which feeds the Umsindusi, and the Sampofu river, running through the Umsinga district and a tributary of the Tugela river.

" In the districts along the north coast, Bilharzia infection seems to confine itself to a few of the smaller spruits.   The Mazule stream and the Umkunyana stream near Melmoth are infected and the spruits around Eshowe also are known to harbour the disease.

" In addition to the rivers mentioned above, there are a number of small streams which are suspected of harbouring the infection.   Among these are the Palmiet stream, a tributary of the Umbilo river, the streams around Stanger, the Sinquasi river, the rivers in the Ginginhlovu district, that portion of the Umhlatuzi which flows through the N'Kandhla district, and all rivers and spruits around Dannhauser.   The spruit running through Burnside Colliery is also suspected."

The following table shows the localities of the better known larval trematodes in South Africa, as well as their most common intermediary hosts.

It is not altogether surprising to find the same cercaria in two closely related molluscs, such as *Physopsis africana* and *Isidora* sp. ? from the same pool at Lourenço Marques, or even in *Physopsis africana* and *Limnaea natalensis* from the Umhlangana at Avoca ; but it is a little surprising to find the same cercaria in two molluscs so far apart as *Limnaea natalensis* and *Tiara tuberculata*, and shows that a cercaria which would die, if an inter-mediary host like *Limnaea natalensis* became dry when the rivers are low, could resist drought until the rivers are flooded again, if choosing such an operculated shell as *Tiara tuberculata* as its temporary host.

In the infested areas of Natal a large proportion of *Tiara tuberculata* are infested with xiphidiocercariae.   At Potchefstroom, in the Transvaal, infestation of *Isidora schackoi Jickeli* with amphistomes is also very heavy. *Physopsis africana* from the Umsindusi at Pietermaritzburg is heavily infested with *C. secobii*, whilst this same species from Sydenham is particu-larly heavily infested with *S. haematobium*. *Limnaea natalensis* from Sydenham is very heavily infested with *C. pigmentosa*, the cercaria of *Fasciola gigantica*.

During the last three years, these investigations have been carried on under the auspices of the Streatfeild Research Trust of the Royal Colleges of Physicians and Surgeons.

[TABLE

	Intermediary Hosts.	Localities.
Monostomes—		
Cercaria oblonga .	Limnaea natalensis Krs.	Port Elizabeth.
	Tiara tuberculata Müll .	Umgeni.
C. fulvoculata . .	Limnaea natalensis Krs.	Mayville.
Amphistomes—		
C. frondosa .	Isidora tropica Krs. .	Mayville.
	Isidora natalensis (Krs.)	Amatikulu.
	Isidora forskali Ehrenb .	Umgeni.
	,, ,, ,,	Cator Manor.
	Isidora schackoi Jickëli .	Potchefstroom.
Xiphidiocercariae—		
C. cawstoni .	Physopsis africana Krs. .	Mayville.
	,, ,, ,, .	Umbilo.
	Limnaea natalensis Krs.	Mayville.
	,, ,, ,, .	Umhlanga.
	,, ,, ,, .	Port Elizabeth.
C. humilis .	Physopsis africana Krs. .	Umhlangana.
	Limnaea natalensis Krs.	Umhlangana.
	,, ,, ,, .	Umgeni.
C. cephaladena. .	Isidora sp. ? . .	Umgeni.
C. ingracilis .	Isidora sp. ? . .	Umgeni.
Echinostomes—		
C. caudadena .	Planorbis pfeifferi Krs. .	Merebank.
C. constricta .	Physopsis africana Krs. .	Mayville.
C. 30-acanthostoma .	Physopsis africana Krs. .	Mayville.
C. arcuata .	Limnaea natalensis Krs.	Mayville.
	Isidora ? schackoi Jick. .	Klerksdorp.
C. cucumeriformis .	Isidora ? natalensis (Krs.)	Merebank.
	Limnaea natalensis Krs.	Mayville.
C. catenata .	Isidora tropica (Krs.) .	Mayville.
	Isidora ? natalensis (Krs.)	Merebank.
	,, ,, ,, ,,	Umgeni.
	Planorbis pfeifferi Krs. .	Mayville.
	,, ,, ,, .	Rustenburg.
	Limnaea natalensis Krs.	Amatikulu.
	,, ,, ,,	Rustenburg..
	,, ,, ,,	Magaliesburg.
Fasciolae—		
C. pigmentosa . .	Physopsis africana Krs. .	Umhlangana.
	Limnaea natalensis Krs.	Sydenham.
	,, ,, ,, .	Lake Chrissie.
Cystophorous Cercariae—		
C. macrura .	Planorbis pfeifferi Krs. .	Merebank.

	Intermediary Hosts.	Localities.
Bucephalus—		
sp. nov. . . .	Modiola capensis Krs. .	Umgeni.
	,, ,, ,, .	Illovo.
Schistosomes—		
S. haematobium .	Physopsis africana Krs. .	Sydenham.
	,, ,, ,,	Mayville.
	,, ,, ,,	Port Elizabeth.
S. mansoni . .	Physopsis africana Krs. .	Sydenham.
	,, ,, ,,	Mayville.
	,, ,, ,,	Ottawa.
S. bovis (c. octadena)	Physopsis africana Krs. .	Sydenham.
	,, ,, ,, .	Mayville.
	,, ,, ,, .	Pinetown.
C. gladii . . .	Isidora schackoi Jickeli .	Potchefstroom.
C. secobii . .	Physopsis africana Krs. .	Pietermaritzburg.
	,, ,, ,, .	Pinetown.
C. oculata . .	Physopsis africana Krs. .	Mayville.
		Lourenço Marques.
schistosomes sp. ? .	Physopsis africana Krs. .	Magaliesburg.
	,, ,, ,, .	Mulder's Drift.
	,, ,, ,, .	Rustenburg.
	,, ,, ,, .	Lourenço Marques.
	,, ,, ,, .	Umhlatuzana.
.	Isidora tropica (Krs.) .	Mayville.
	Isidora forskali Ehrenb .	Tongaat.
	Isidora sp. ? . .	Lourenço Marques.
	Planorbis pfeifferi Krs. .	Mayville.
	,, ,, ,, .	Lourenço Marques.
schistosomes sp. ?	Physopsis africana Krs. .	Pinetown.
redia-produced.	Limnaea natalensis Krs. .	Umgeni.

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STUDIES IN THE MORPHOLOGY OF *SELAGINELLA PUMILA*, SPRING.

Part II.—The Cones, Spores, and Gametophytes.

By A. V. Duthie.

(With twenty Text-figures.)

Vegetative reproduction, so common in the genus *Selaginella*, does not occur in *Selaginella pumila*. Multiplication is effected entirely by means of spores, and, as each adult branch of the leafy axes ends in a cone, the number of spores produced is large in proportion to the size of the plant.

Young cones begin to form early in August, and before the end of that month the four megaspores may be recognised in the basal sporangia of some of the cones. Shedding of the ripened spores takes place during October and November, and may continue into December, the time depending to some extent on habitat and climatic conditions. My observations are based largely on material collected in the neighbourhood of Stellenbosch.

The mature cones vary much in size ; the largest noted were 18 mm. long and about 2½ mm. broad. Each cone is rectangular in shape, and consists of a central axis which bears four compact vertical rows of sporophylls (figs. 1, 2, 4). The arrangement of sporangia is very regular, especially in the lower and central region of the cone, where, as a rule, megasporangia occupy two of the sporophyll rows and microsporangia the other two (figs. 4, 5). In the upper part of the cone, however, irregularities are more frequent, and it is not unusual to find microsporangia only, terminating the four rows. The extreme apex of the cone bears a few undeveloped sporangia.

The anatomy of the cone axis does not differ in any essential features from that of the vegetative stem (6). In the centre of the stele is a well-defined group of metaxylem tracheides with two peripheral protoxylems. As a rule two layers of thin-walled phloem elements separate the xylem from the single layer of large pericycle cells. The stele is enclosed in a lacuna which is bridged by the elongated cells of the endodermis.

The sporophylls, which are among the most highly specialised of any in the genus, were described by Sykes and Stiles in 1910 (14). Each is furnished with a short stalk, an upward-directed lamina which to some extent protects the sporangium above it, and a downward-projecting flap which overarches the upper part of the sporangium immediately below (figs. 3, 4). The resemblance in the form of the sporophyll to that of such species of Lycopodium as *L. cernuum* or *L. carolinianum* is very marked. The sporophylls of plants growing in shady places on hill slopes are usually

FIG. 1.   FIG. 2.

somewhat recurved, with the result that the sporangia are partially exposed (fig. 2). On the other hand, cones collected on the flats tend to have rigid and erect sporophylls which effect the more perfect protection of the sporangia (fig. 1).

The two lateral strands of " transfusion tracheides " which flank the vein of the vegetative leaf (6) are very strikingly developed in the sporophyll. They expand markedly at the base of the lamina, where they end blindly, without as a rule entering the leaf-stalk (fig. 3).

As in the foliage leaf, stomata are confined to the aligular surface. They occur over the middle region of the leaf and near the dentate margin in hillside cones. In cones found on the flats they are scattered over the whole of the under surface of the lamina, and may occur on the leaf-margin
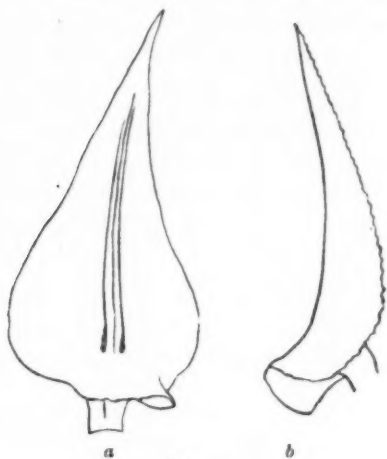
a   b   FIG. 3.
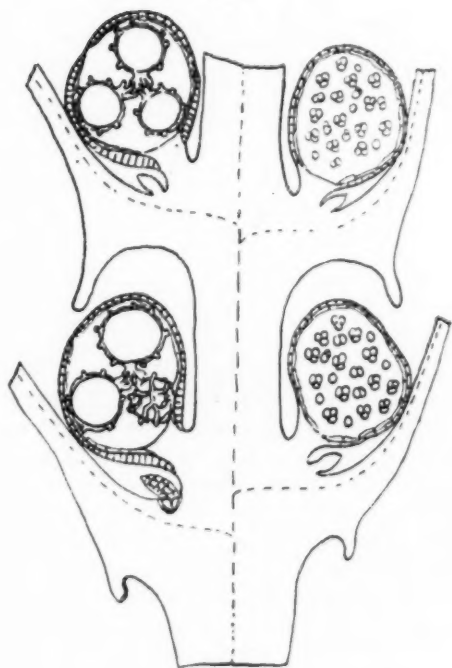
FIG. 4.

itself.   The marginal and surface cells in these sporophylls are not pro-
duced into teeth as are those of the hillside form.   Stomata are absent
from the basal flap.

It will be noted from the figures that the decurrent base which is so
striking a feature of the vegetative leaf (6), is absent from the normal
sporophyll.   Sykes and Stiles describe (14) and figure a decurrent dorsal
swelling to the sporophylls of *S. helvetica*, and suggest that it may possibly
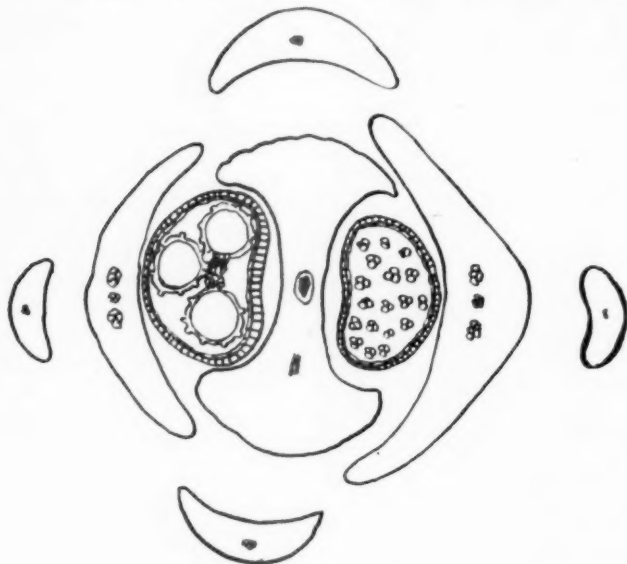
Fig. 5.

represent the rudimentary remains of a well-developed basal flap (such as
is present in *S. pumila*), which has here become fused with the stem.

The limits of the cone are usually clearly defined, there being an abrupt
transition from the lowest sporophylls with their projecting flaps to the
foliage leaves with their decurrent bases.   Instances were, however, noted
in which the lowest leaf of a compact cone was intermediate in character
between a typical sporophyll and a foliage leaf.   A perfect or imperfect
sporangium was developed in its axil.   Again, one or two of the leaves of
the axis immediately below the base of the cone, but separated from it by
a shorter or longer interval, may resemble a sporophyll in the greater breadth
of leaf-base and the presence of a small flap.   One or more abortive sporangia
may occasionally be found below the limit of the cone proper (fig. 6).

Rooted plants, some of which had begun to form cones, were removed to the greenhouse and laboratory, where they were kept shaded and well watered for over a month. Cones which had formed under the changed conditions were loose, with widely-reflexed sporophylls. Elongation of the cone axis had separated the sporophylls, so that the basal flaps did not touch the sporangia below. A number of cones, which were partially formed before the change of environment, showed compact and erect sporophylls in the lower half, and loosely arranged, spreading sporophylls in the upper half. Abnormalities such as irregularities in sporangial arrangement, abortion of sporangia and of spores, were more frequent than in material which had matured under normal conditions. In one plant a fertile microsporangium was found in the axil of an ordinary leaf well below the base of the cone, and separated from the lowest sporophyll by five foliage leaves.

As in other investigated species, the young sporangia are identical in the early stages of development (figs. 7, 8). They arise from stem tissue, and even when mature are clearly seen to be inserted on the axis (figs. 4, 7). A single layer of tapetal cells separates the mass of spore-mother cells from the two-layered wall. In the microsporangia all the spore-mother cells produce spores (figs. 9, a, b; 10), whereas a single spore-mother cell develops in the megasporangium (fig. 11).

Mature mega- and microsporangia are of approximately the same size, and are furnished with short stalks (figs. 4; 12, a, j). Sykes and Stiles (14) have drawn attention to the presence of elongated lignified elements in the stalks of the microsporangia.

Fig. 6.

The megasporangium shows as a rule four rounded protuberances, corresponding to the four enclosed megaspores (fig. 12, a). The average breadth is 825 μ. In the great majority of normal sporangia two spores lie in the saucer-shaped lower piece of the wall, and the other two lie in the upper part of the sporangium at right angles to the pair below. Only two sporangia were observed in which three spores were situated below and one above, resting on the lower three. Though in general four spores of equal size mature in each megasporangium numerous exceptions to this rule were noted. One, two, or three spores may develop, and the remaining spores of the tetrad be stunted or abortive (fig. 12, f). The position in the sporangium of the abortive spores may vary. One sporangium examined was found to contain a single very large spore, one very small spore, and two of intermediate size. No instances were noted of megasporangia in which the reduction in the number of fertile spores could be

FIG. 7.

FIG. 8.

a   FIG. 9.   *b*
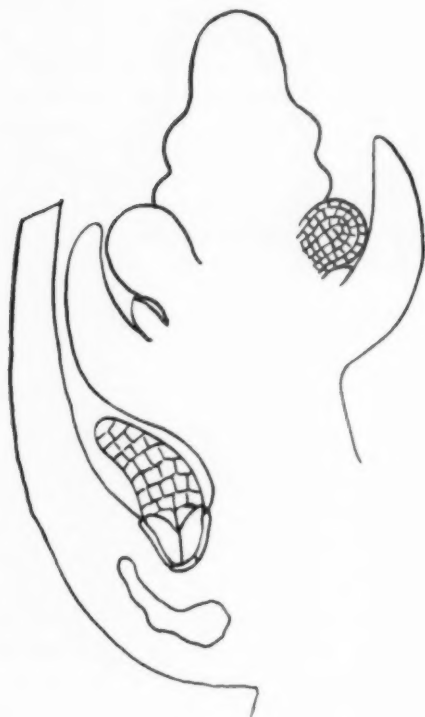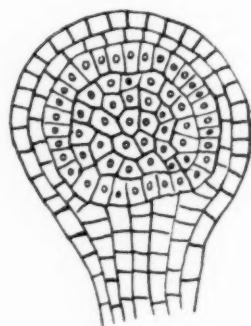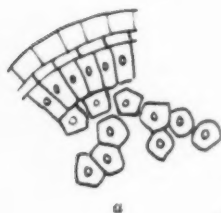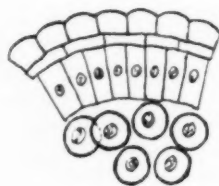
attributed to the suppression of the second division of the spore-mother cell. No sporangium was found to contain more than four spores.*
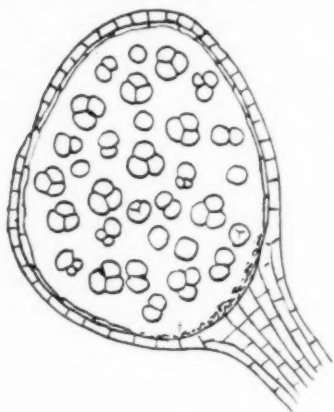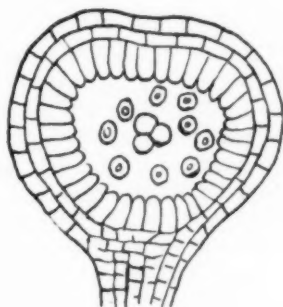
FIG. 10. FIG. 11.

The sporangial wall in drying splits along lines of weakness which are clearly seen in the unopen sporangium (fig. 12, *a, b*). The entire process of the gradual rupturing of the wall and the ejection of the spores can be

a   *b*   *c*   *d*   *e*   *f*

g   *h*   *i*   *j*   *k*   *l*
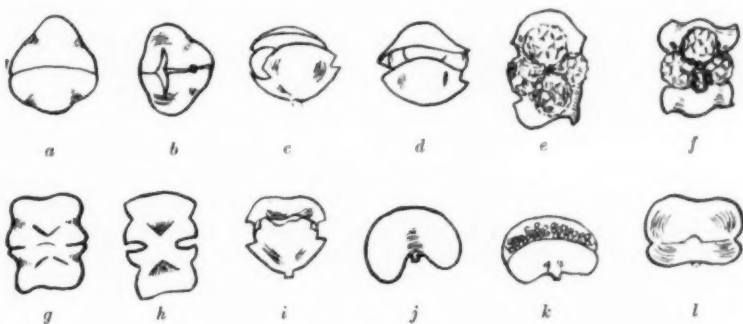
FIG. 12.

readily studied under a dissecting microscope if care is taken to cement the stalk of the closed sporangium to a slide (fig. 12, *c–i*). The dehiscence

* Material of *Selaginella Kraussiana* growing in a local greenhouse which was examined at the same time showed several megasporangia with an increase of the normal spore number to 8, due doubtless to the development of two spore tetrads.

cracks divide the sporangial wall into two upper valves and a lower boat-shaped piece which may remain entire or split further along both sides, almost down to the stalk. The valves as well as the lower piece of the wall appear to be involved in the ejection of the spores. As a rule, all four spores are shed simultaneously, though the following varieties were noted :—

1. One basal and one valve spore shot out together, followed by the remaining spores.

2. One basal and one valve spore shot out ; the remaining spores left in the sporangium.

3. Two spores ejected first, then the third, the fourth remaining in the sporangium.

In a sporangium which had one valve cemented to the slide, the spore in this valve remained in position while the spore belonging to the second (free) valve was ejected. The two basal spores were also ejected, but not to any great distance.

In one cone from which most of the spores had been shed, an open megasporangium was noted about half way up the axis, which had retained one large and one very small spore. Two cones were also noted in which an open basal megasporangium had retained its four megaspores ; but on moving the cone the spores were flicked out. If a dehisced megasporangium be placed in potash it recovers its shape completely in about sixty seconds. The ejection of the spores can be studied in preserved as well as in fresh material. No attempt was made to investigate the details of the mechanism involved in spore-ejection, which has been the subject of repeated research by several authors ; but it is very effective in this species. The maximum distance to which the spores were hurled was found to be 34 cm., or about 1000 times the diameter of the spore. The greater number of the spores were, however, thrown to less than half this distance.

The reniform microsporangia are about 950 μ wide and 504 μ broad from stalk to apex (fig. 12, j). The dehiscence is vertical, and divides the sporangium into two valves, which do not separate right down to the stalk (fig. 12, k, l). There is no indication of forcible ejection of the microspores. In erect cones which have reached maturity in still air the two rows of dehisced microsporangia, with their heaps of brilliantly coloured, exposed spores, can be readily seen with the naked eye, while the corresponding megasporangia are empty. As the valves of the open microsporangia gape widely, a few of the spores are spilled and fall vertically. Torsion of the drying stem may partially or entirely empty the microsporangia of their contents, and the slightest puff of wind will aid in scattering the spores.

In the great majority of cones examined, the lowest microsporangia

were found to dehisce a little in advance of the megasporangia. One cone showed six dehisced microsporangia, while all the megasporangia were still closed.

The colour of the ripe megaspore is pale lemon.* When the four megaspores of a tetrad have developed equally, the average diameter of each is about $350\,\mu$. The exospore is coarsely reticulated. At the apex of the spore is a conspicuous spongy protuberance formed in part from wing-like expansions of the exospore in this region, and in part from the development of the exospore beyond the comissural ridges (figs. 13, 14). In spore cultures microspores are often found clinging to this protuberance, and its curtain-like folds appear to afford some measure of protection to the female prothallus and the young embryo.
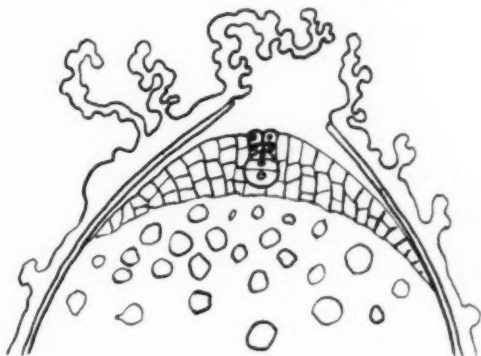
FIG. 13.   FIG. 14.

The spore cavity contains a dense oil in which are embedded numerous protein grains (figs. 14, 15). These reserves do not completely fill the spore, for, on drying, the exospore collapses, forming a marked depression at one point. The shrivelled spore completely recovers its shape if placed in water for a few minutes.

After soaking or boiling in potash the exospore may readily be removed from the colourless mesospore.

For the study of the prothalli, numerous room-cultures of mega- and microspores were made on moist earthenware, filter-paper, and in covered watch-glasses. Small tins with perforated sides and with the ends removed were sunk at various places in the Stellenbosch flats, and the surface soil in these tins was thickly sown with spores during December of 1921. A few spores which had been naturally shed were also collected on the ground near the withered remains of the parent plants.

* Light orange-yellow (Ridgway's " Colour Standards and Colour Nomenclature ").

No cellular structure can be recognised in the megaspores at the time of shedding. In room-cultures made on moist earthenware at the end of 1921, with spores collected the same season, traces of prothalli were noted in a few of the spores within seven days (fig. 16, *a*, *b*). In twelve days' time some
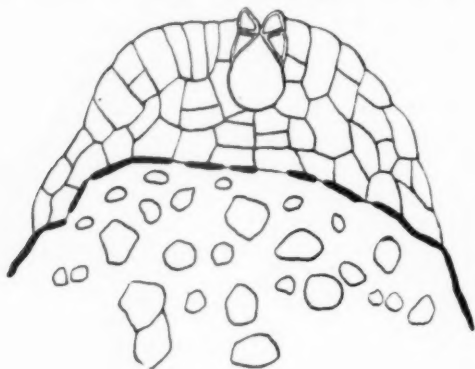
Fig. 15.

of the spores showed an apical prothallus with a single centrally placed archegonium (fig. 14), and a few days later several archegonia were noted in advanced prothalli.

The neck of the archegonium consists of two tiers of cells, four cells

a   *b*   *c*
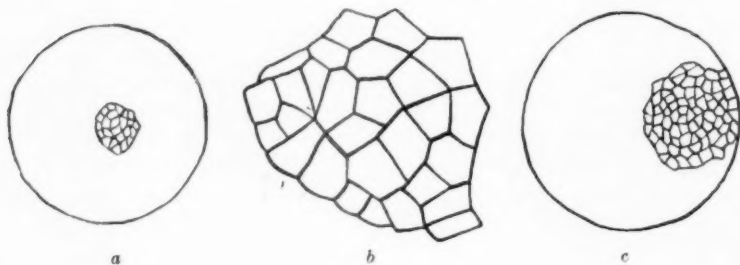
Fig. 16.

in each tier (fig. 17, *a*, *b*). No instances were noted of a three-tiered neck such as has been described by Bruchmann in *S. spinulosa*.

The first sporophytes were observed in cultures twenty-six days old. The great majority of the spores produced prothalli sooner or later; only a few of the smaller spores were abortive.

A marked feature of the cultures is the irregularity in the time of ger-

mination of the spores, due doubtless to differences in the maturity of the spores when shed.

Samples of spores were taken from the experimental tins on the Stellenbosch flats on March 18th. The total amount of rain which had fallen since the sowing of these spores was 4·77, spread over eighteen days. Many of the spores were found to be eaten out, apparently by insects. Of the uninjured spores examined some showed an apical prothallus, while others showed no sign of germination.

Sporophytes were not noticeable in these tins or on the surface of the flats until the end of April and the beginning of May.

Certain irregularities occurred in some of the room-cultures which will be considered in the account of the embryo.

As the cap of prothallial tissue increases in age the lower cell-walls usually thicken, producing a well-defined diaphragm which separates the

a   *b*
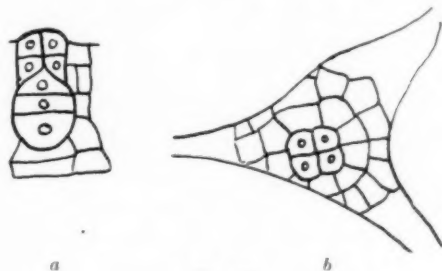
FIG. 17.

small-celled archegonium-bearing tissue from the food reservoir (fig. 15). In the presence of a diaphragm, the female gametophytes of *S. pumila* resemble those of *S. Kraussiana* and *S. Poulteri*.

The storage reservoir of the spore never becomes cellular as it does in the great majority of described species.

Fig. 18 represents outline drawings of megaspores which remained on moist earthenware for a period of five months, but failed to produce embryos. The spores have been freed from the exospore by heating in potash. It will be noted that two of the prothalli show swellings near the periphery. These may possibly represent traces of the rhizoidal protuberances which Bruchmann has described as occurring in all species investigated by him; but no trace of rhizoid development was observed either in room-cultures or in prothalli which had developed under natural conditions.

The orange-red * microspores which are produced in large numbers in

* Orange-rufous (Ridgway's " Colour Standards and Colour Nomenclature ").

the microsporangium remain united in tetrads (figs. 4, 10, 19).   The surface
of the spore is covered with fine rod-like projections.   The reduction in
size of one or more spores of a tetrad, already noted in the discussion of
the megaspores, is still more noticeable here, and abortion of the reduced
spores is very frequent (fig. 19, *a, b, c*).   When the four spores of the tetrad
develop equally, the diameter of each is about 40 μ, though the size is by
no means constant.

a   *b*   *c*
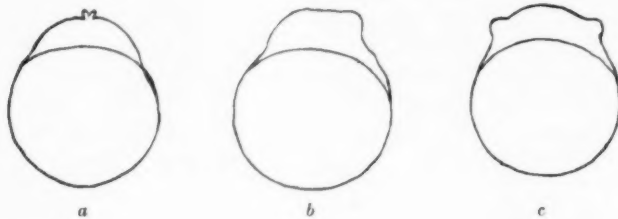
Fig. 18.

Germination begins before the spores are shed, but the degree of develop-
ment reached by the spores of a mature microsporangium varies within
wide limits.   Even the condition of the spores of a single tetrad may differ
considerably.   As is well known, the cell walls of the male gametophyte
do not stain readily.   If, however, the spores are examined in carbolic
acid, the structure can be made out with ease.   Fig. 20 shows spores in
various stages of development, but no attempt was made to trace the

a   *b*   *c*   *d*   *e*   *f*
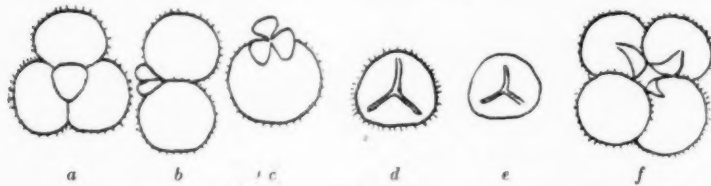
Fig. 19.

succession of the dividing walls.   The number of sperm-mother cells pro-
duced varies from over a hundred in the best-developed spores to under
fifty in those which are stunted in size.   Some of the spores in hanging-
drop cultures showed rupture of the outer wall after nine days.   Motile
sperms were first noted in cultures sixteen days old, but it is probable
that the most advanced spores liberate sperms earlier than this.   In
cultures of microspores which had been kept moist for fifty-four days, the
majority of the spores were found to have shed their sperms, but a few
still showed cellular structure.   Experiments indicate that not only is

sperm-liberation in a culture continued over a long period, but also that the male prothallus, even after the organisation of the sperm-mother cells, is not injured by prolonged or intermittent drying. Microspores which had been kept moist in a watch-glass for about a fortnight were allowed to dry completely, and to remain in this condition for three days. Some time
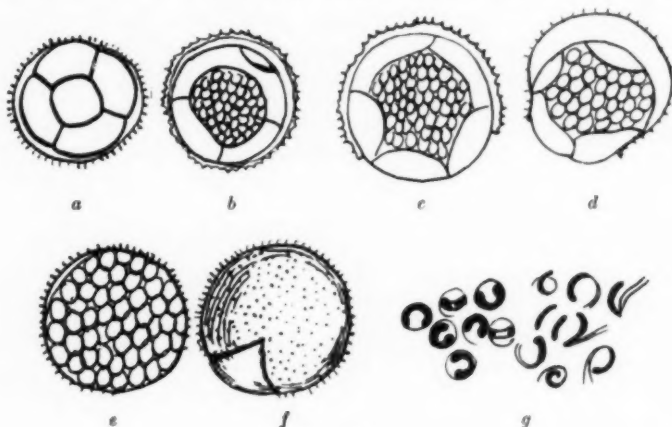
Fig. 20.

after re-moistening the liberation of motile sperms was observed. The culture was again allowed to become dry, and after five days water was added, when sperms were liberated in about an hour. The culture was alternately dried and moistened with the same result. It was finally left in a dry condition for sixty-one days. Even after this prolonged drying myriads of motile sperms were liberated three hours after moistening.

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EXPLANATION OF FIGURES.

Fig. 1. Large cone from flats near Stellenbosch.

Fig. 2. Small cone with recurved sporophylls, from hillside.

Fig. 3. *a.* Sporophyll of 1, cleared in potash to show vein. *b.* Sporophyll of 2, seen from the side.

Fig. 4. Longitudinal section through lower part of cone.

Fig. 5. Transverse section of cone.

Fig. 6. Abortive sporangium below base of compact cone.

Fig. 7. Longitudinal section through young cone.

Fig. 8. Young sporangium showing spore-mother cells.

Fig. 9. Part of young sporangium showing two-layered wall, tapetum, and spore-mother cells.

Fig. 10. Longitudinal section through microsporangium shortly before dehiscence.

Fig. 11. Young megasporangium with single spore-tetrad.

Fig. 12. *a–i.* Megasporangia. *j–l.* Microsporangia.

Fig. 13. Megaspore.

Fig. 14. Section through germinated megaspore.

Fig. 15. Section through old female prothallus showing diaphragm.

Fig. 16. *a, c.* Germinating megaspores from seven days' culture cleared in potash and freed from outer wall. *b.* Young prothallus highly magnified, seen from above.

Fig. 17. *a.* Archegonium in vertical section. *b.* Transverse section through apex of prothallus, showing lower tier of neck cells of archegonium.

Fig. 18. Megaspores with prothalli, from old culture. The outer spore wall has been removed by pressure after heating in potash.

Fig. 19. Microspores. *a–c.* Tetrads, showing abortion of spores. *d.* Isolated microspore. *e.* Microspore with outer wall removed. *f.* Germinating tetrad of microspores.

Fig. 20. *a–f.* Germinating microspores. *g.* Spermatozoids, liberated from antheridium.

A PRELIMINARY GENETIC STUDY ON THE OSTEOLOGY OF THE GRIQUAS.

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(Government Research Scholar.)

(Under the auspices of the Government Research Grant Board.)

(With eight Text-figures.)

SECTION I.

INTRODUCTION.

THIS report, which must be regarded at the present stage as being of a preliminary character, gives an account of the work carried out during the year 1919 and the first quarter of 1920.

Though by no means conclusive or complete, the results of the work are sufficiently promising to justify the undertaking of this particular piece of investigation, and to encourage me, as soon as referential data are accessible, to publish the results.

I wish to make it clear that on many points the possibilities of arriving at any definite conclusion at present are precluded owing to the lack of literature and the difficulty in obtaining satisfactory data for embodying in tables and graphic diagrams of a comparative nature.

SECTION II.

THE OBJECT OF THESE INVESTIGATIONS.

The object of this investigation was to seize in time the opportunity of studying the osteological features of the Griquas, and to determine as far as possible to what extent the parental characters have been transmitted to this mongrel horde, in how far these traits have blended, and to what extent ancestral features are still patent in the skeleton.

The Griquas offer unique opportunities for this study, since there is no doubt in regard to their actual origin, and bastard communities are by no

means common or accessible at the present day.   In other parts of the world
the opportunity for carrying out such investigations has vanished, owing
to the lapse of time and the consequent unavoidable complexity due to
confused intermingling.

The significance of a study pursued along these lines is great.   In the
first place, in anthropological investigations concerned with prehistoric
man we are compelled, in attempting to unravel the origin and inter-
relationships of the various types, to rely on skeletal structures, despite
the assistance undoubtedly rendered by cultural implements, ethnical
studies, etc.

Secondly, many historical investigations concerned with the origin of
peoples do not reach final and trustworthy conclusions, and the extent to
which osteological features can be relied on in delineating the past history
of nations has an important bearing on such investigations.

Again, many of the difficulties which confront anthropologists in dealing
with prehistoric remains of man are frequently explained away as being
due to pathological conditions.

Further, osteological studies such as that attempted here have
value as bearing on the problem of heredity when applied to the
human race.

I do not for a moment imagine this work to be conclusive or the ideas
to be beyond criticism ; far from this ; but even if its value should merely
rest on the actual anthropometrical data contained, I am content to have
added this very small item as a contribution to the insatiable spirit of
Science.

SECTION III.

Brief Historical Note.

The group of nomad half-breeds which came into being during the
eighteenth century on the inland plains of South Africa typify excellently
the word " horde " in its ethnological significance.

They are described in Lord Charles Somerset's time as being almost
as degraded as the Bushmen ; they were at that time merely a roving band
of half-breed descendants of Europeans and Hottentot women who had
migrated to the territories south of the Orange River from the Cape and the
south-western portions of the Colony.   Before their occupation of the
country it was inhabited by the Bushmen and Hottentots, and members
of their races, as well as Kaffir and Bechuana refugees and evil characters
from the Colony, swelled the ranks of the Griquas constantly, until they
numbered several thousands in 1803, when Anderson persuaded them to
settle at " Klaarwater," founding the town of Griquastad.

Under the leadership of Barend Barends the community increased, and a considerable trade in cattle, guns, and liquor developed through the agency of European scoundrels from the Colony ; so that by 1816 they were becoming a considerable menace, and had three hundred guns in their possession. This danger was increased by the constant instigation of the marauding Conraad Buys (who had married Gaika's mother) and his Gonah-Hottentot associate " Dantser."

In 1822, consequently, Melville was appointed political agent at Griquatown, although he was so ill supported as to be practically powerless. At his suggestion, however, Andries Waterboer was elected captain of a section of the Griquas, to the chagrin of Adam Kok (who had joined with his band from Namaqualand) and Barends, who soon after moved east, and settled between the Orange and the Modder rivers. Plundering the weaker Bantu tribes in their neighbourhood, the Griquas were a sporadic nuisance to the colonists, until they and their chief, Adam Kok III, were placed under British protection in 1843. In 1848 they assisted the British against the Boers, with the result that when the Orange Free State was formed in 1861–1863 Kok and three thousand of his people migrated to Griqualand East, selling their rights north of the Orange to the Orange Free State for £4000. In their new habitation they founded Kokstad.

In 1852 Nicolaas Waterboer succeeded to the captaincy, and from this time the status of the horde rapidly declined, a disruption which was furthered by the discovery of diamonds on the Vaal River in 1867, and subsequently at Kimberley, drawing many of them thither for employment, and finally scattering their numbers completely.

Such in brief is the history of the Griquas. Considered as an ethnical group, nothing is to be gained in studying them further ; it is when we approach them in their anthropological significance, however, that much is to be gained by their investigation. For here we find in its early stages that process of miscegenation which has resulted in the formation of most of the nations and tribes of to-day, and which has been operating in all parts of the earth from the earliest days of man's existence.

In the Griquas we have a fit group for the study of the results of blending —but it must not be forgotten that it is a subject beset with peculiar difficulties. For although having the first advantage of knowing which races are concerned in the blend, and of previous studies on these races, we are faced with the fact that very little previous work has been done in this direction, and confirmation of our results from other sources is thus difficult to obtain.

As the so-called " Griqua " of to-day seems to signify almost any sort of a wandering mixed breed, we have relied for our data on material which,

to the best of our knowledge, represents the Griqua of last century.   Firstly, as regards his external appearance, the only description we have discovered as yet is that in Arbousset's Narrative (p. 19, 1846), where he mentions that in the Cape bastard the white blood predominates, in the Griqua the Hottentot ; and adds, " the Griqua is less of a mongrel than the bastard —his features are better defined, his bearing more manly, his hair more crisp, his complexion more dark."

The distribution of the Griquas was limited to the districts still known as Griqualand East and West respectively, the latter being the original centre of concentration of the horde, and affording the material for the present inquiry.

SECTION IV.

COLLECTION OF MATERIAL.

It must be admitted that in the majority of cases the skeletons obtained could only be taken to be those of Griquas on the verbal evidence of the people living in the neighbourhood of the graves, and that it is by no means beyond possibility therefore that there may be in some cases Bantu skeletons included as Griquas ; it is most unlikely that Hottentot material could have been included, as the very outward appearance, stature, etc., seems altogether to preclude this error.

On the other hand, the distinctness of the indices obtained from those for Bantu and Hottentot specimens would seem clearly to show that the great majority of skeletons here considered must actually be of Griqua origin.

The material was all collected in the district of Griqualand West during the months of June and July.   The first locality visited was the farm of " Devondale," near Grange Siding ; here especially the greatest courtesy was shown me by the owner, Mr. P. J. Marais, to whose assistance personally, and by several labourers, the search for material was greatly facilitated. On this farm over twenty graves were opened, but only four specimens were obtained in a suitable state of preservation, two of these being Bush-men by repute (as was also borne out by the skulls and the proximity of pteroglyphs, and the mode of burial), and the remaining two were taken to be members of a party of Griquas who had migrated there from " Ramah." A peculiarity of all the graves at " Devondale " was the fact that they had been filled with round boulders—to which was frequently due the shattered state of the remains.

I returned to Kimberley with this material, and then proceeded by motor to " Driekop," on the Riet River, the property of H. Aucamp, Esq. ; here, during several days' search, four good skeletons were disinterred.

The natives domiciled on the farm averred that their parents had always spoken of the graves as being of Griqua origin.

With these four skeletons may be included the skull of a young male dug up by me in February 1918, a few yards from the graves above mentioned : though undoubtedly not of Bushman stock, the skeleton was buried in characteristic sitting posture, with a clay pot on the cranium.

Returning again to Kimberley to store the material, I proceeded by rail and car to " Ramah " Manor, near Belmont, where Mr. F. Attwell showed me the greatest hospitality.   Here six good skeletons were obtained : a large number of other graves were opened, but many of the skeletons were those of very young individuals, and were not retained for measurement.   As " Ramah " had been a Griqualand mission station founded by Moffat and occupied by Griquas during the time of Mr. Attwell's father, there can scarcely be any doubt that these skeletons are authentic.

Again returning to Kimberley to store the material, I spent a week in motoring round farms near the Modder River, and after meeting with very unsatisfactory results at first, finally secured six skeletons at " David's Graf " (so named after the grave of David Davids, a Griqua lieutenant), which had once been a beacon on the boundary of the Orange Free State.

Mr. Pretorius of this farm, and several other residents in the neighbourhood, assured me that their predecessors had told them that near the site of the graves a band of Griquas had once settled temporarily—certainly the burials had not taken place during their generation.

It was most peculiar that one of the skeletons, rather removed from the rest, was buried in a chamber formed by flat stones, about the size of a coffin ; the body was quite near the surface, but the soil was exceedingly hard, and had evidently been undisturbed for many years.

Throughout my quest for skeletons I was received by the farmers with the greatest courtesy and hospitality, and to them and also to Mr. G. L. Aucamp, who accompanied and assisted me, I am very largely indebted for whatever success I attained in this direction.

SECTION V.

PAST WORK ON THE SUBJECT OF BASTARDISATION.

There has only once been an actual interest in the questions involved in bastardisation, prior to some very recent work on the subject ; that was due to an effort to arrive, by investigating the relations of negro and white, at a decision as to whether in the white and the black races we do not have

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in reality two specifically different groups of mankind represented.   In
this connection there appeared during the first half of the nineteenth century
a number of rather abstract treatises on the problem : in 1858, when the
Anthropological Society of Paris was established by the efforts of Broca,
the bastard problem was allotted an important place in the programme
of action ; in spite of this, however, no solution to the question was arrived
at :   Kollmann's " Dauertypus " (postulating the constancy of certain
race types) and Von Luschan's theory of racial admixture were the main
noteworthy theoretical attempts at a solution.

The whole question revolves, however, about considerations of heredity
and Mendelism, and we have in this connection some very instructive
data in relation to these phenomena in man.   Most of the facts first
accumulated were concerned with pathological inheritance, and it was
found that one could demonstrate with certainty that for many patho-
logical phenomena Mendelian laws held good—that in the union of indi-
viduals with certain ascertained lethal manifestations with others who
were normal in this respect, the modern doctrines of transmission of
characters were applicable.

But it is only in very recent years that normal characters of man,
anthropological criteria, racial peculiarities, were investigated similarly.
Here the names of the Davenports stand foremost : they sought to subject
to analysis from this standpoint the inheritance of hair-colour, and form,
eye-colouring, and pigmentation of the skin in American Europeans, and
then also in Negro-European mixtures.

In this connection Hurst (1908) is also deserving of mention, as well as
the comprehensive insight of Karl Pearson and his school, whose efforts
elucidated the cross—or inheritance—methods of Mendelian experimenta-
tion regarding many pathological and normal as well as psychical
characters.

Finally, there appeared an interesting study on the transmission of the
Jewish type by Salaman in 1911, and a thoughtful work by Frans Lenz
(1912) which throws some light on the significance of studies of heredity
applied to anthropology.

These questions all have some bearing on the problem of bastardisation,
but the actual question itself was not approached till 1907, when the efforts
of the Zaborowski revived the old intentions of the Anthropological Society
of Paris to investigate the question, and a committee was appointed to
institute a comprehensive inquiry into racial-mixture.

In the suggestions published by the commission in 1908 the problem
was very aptly spoken of as one of the most difficult and clouded of anthro-
pological queries, on which we possess no enlightenment or useful data.
The hypotheses advanced were untenable, however, as they ignored all the

teachings of Mendelism, all the thousands of authentic experiments on plants and animals.

It is not with theoretical construction that we can hope to arrive at success at this stage, not with hypothetical synthesis, but with detailed and critical investigation by anthropological workers, as a basis for a later full analysis founded on the actual results. In this spirit a treatise by Dr. Eugen Fischer (1913), on Die Rehobother Bastaards und das Bastardie-rungs-problem beim Menschen, has appeared, constituting, I believe, the only application to physical anthropology of the questions of heredity and hybrid-genesis.

SECTION VI.

The Nature of the Problem.

It seems probable that Mendelian laws will ultimately prove to be the crux of the whole question; but it is patent that whereas the biologist can test by actual controlled experiment the workings of variation and heredity, the anthropologist cannot perform such experiments, but must be content to observe carefully those instances which nature has been instrumental in putting before him.

The greatest of such opportunities, the racial crossing of white and black in America, has passed by uselessly, uninvestigated to science, as Fischer says, " Unwiederbringlich sogar, denn Kein Mensch wird je die Aszendenz der heutigen ' Farbigen ' in Amerika angeben konnen." Other instances are to be found in various parts of the world, in the Pacific, in South America, in Australia, but the most opportune time for their investi-gation has passed, and the bastards of Southern Africa, the Rehobothers and the Griquas, afford the only cases to-day where the action of ex-traneous elements has not yet served to obscure totally the results of the first racial mixing; but hitherto works treating on the anthropological relations of Africa have always passed over the bastard communities as being scientifically uninteresting, owing probably to the fact that the ethnological standpoint has apparently been the most attractive to workers in this country at the expense of inquiry of a more strictly biological nature.

Bastardisation is thus the problem which this study on the Griquas is intended to approach—if merely to accumulate data which may be useful to future workers. Bastardisation may be termed the sexual union of heterozygous individuals, using the term in a wider sense to imply innate physical racial differences, and not in the more restricted sense of Geddes, Thomson, and others, to refer to sex-differences only.

With pure parental forms the question would be complex in itself, but

it becomes much more so when we are forced to realise that no human race is absolutely " pure."

The two chief parties concerned in the production of the Griqua were the European and the Hottentot : that the former cannot be pure is evident from the working of Mendelian laws revealed by the researches of the Davenports ; and the Hottentot is just as impure, for Von Luschan (1906–1907) has shown that the race certainly possesses linguistic elements of an Hamitic origin from Northern Africa, and extraneous somatic infusion also (probably of Bantu blood) comparatively recently.

It must be borne in mind that the Hottentot and white are differentiated not only in one but in a great many respects, physically and physiologically, and that even the skin-colour, for instance, is dependent on a large number of factors : in the " F2 " generation there could therefore only in many thousands of individual cases appear an isolated one having either purely white or purely Hottentot characters.   As Bauer remarks, when one crosses two races which differ in some twenty factors, say, one has to deal with an " F2 " generation in which an endlessly complex association of these is possible $(2^{20})^2$, giving over a million-million different combinations.

And what further variations are made possible when we take into consideration that in many of the biological cases now known the dominance of any one allelomorphic character is imperfect, more or less of the recessive character being exhibited !   Add to this the simultaneous operation of isolation and of environment with the influence of heredity, and extraneous factors involved, masking in some degree the true inherited race-qualities !

The most pressing question is the fundamental query as to whether a totally new race can arise by bastardisation, whether the two parental races can mingle, *i.e.* give a new race with new characteristics, which persists as an independent " stable racial group " ?   Approaching such a topic with due caution, we can only say that nothing is proven as yet ; true, one speaks of " mixed races," describes certain groups as racially intermediate to two others, and concludes on these grounds as to their probable origin—but no proof of the reliability of such contentions is as yet forthcoming.

Are we to conclude with Dr. Eugen Fischer that " eine dauerende reine Rasse kan also aus unseren Bastards rein auf den Erbweg nicht entstehen " ? Is it correct to believe that a new type can, as Virchow, Kohlbrugge, and Kollman asserted, never arise by racial crossing ? Is the origin of new races, of typical intermediate forms, in fact, by means of crossing (which has never been proved) to be considered on the whole as very improbable ? Does the final population engendered by a cross therefore always correspond to an " F2 " generation, that is, to a mixture of the parental race-characters

which attain no stability, or, where rejection or selection has occurred, revert to the parental form ?

It is very difficult, in the light of the data at present available, to form a definite opinion. Fischer takes the last-mentioned idea as corresponding with the facts, and compares the Rehobothers to an " F2 " generation. But the possibility arises of the operation of a " balancing " influence, associating certain characters more frequently than others, and gradually bringing about comparative equilibrium in their variation : in other words, the attainment of racial characters varying only by individual peculiarities. This does not seem to me to be as yet totally excluded, and certainly appears to present a tenable working hypothesis. But more data are imperative, as the question is of no small importance.

All the almost immeasurable questions which are passed over with the terms " race " and " people " are involved : the great problem as to whether the admixture of peoples of different races produces a new intermediate race—and if so, how ? whether such a race preserves its unity ? whether it alters with time by virtue of its origin ? whether the parent races again reassert themselves—" disentangle " ? whether a new environment exercises any influence on a migrant race—race origin and race decay ?—all these most complex considerations lead finally to the task of knowing precisely the manifestations, rules, and laws which operate in the crossing of two races, which thus control the nature of the progeny of two variant parents and determine all the characters appearing in this offspring.

SECTION VII.

THE S.A. NATIVE RACES AND THEIR BEARING ON THE STUDY OF THE GRIQUAS.

It is quite clear that in the Griqua we are dealing with a mixed race of European-Hottentot descent, and that the undoubted degree of variation found in these parent stocks, and their significance, must be borne in mind, and these races subjected to analysis before we proceed further. Briefly, the native races in South Africa fall under two headings :—

1. Negro : Bantu.
2. Negrito : Strandlooper, Bushman, Hottentot.

As in the case of all races of man inhabiting the globe to-day some degree of racial admixture must inevitably have occurred, so also in regard to South Africa it must be borne in mind that such a thing as a literally pure race is unknown ; when, however, racial mixture is so remote as to have permitted the attainment of average fixed varietal characters, we can regard the race as a distinct anthropological group.

The Hottentots are generally considered in the light of recent research as being closely allied to the Bushmen originally : their paths must, however, have diverged in very remote times to have permitted the large linguistic changes and ethnical advance and the total loss of the glyptic art.   Owing further to the postulated infusion of Hamitic blood before the migration of the Hottentot southwards, they had increased in stature and acquired different cranial proportions.

Further, if we accept the orthognathous Strandlooper as being representative of the original Bush race, it becomes difficult to accept the subnasally-prognathous Hottentot as a cross-breed between this race and an apparently prognathous Hamitic stock, unless we are prepared to admit the presence of Negro blood, which is also borne out by comparative measurements.

On general anthropometrical grounds the following conclusions have been arrived at by Shrubsall and others, and seem to be justifiable :—

1. The Hottentot is intermediate in all respects between the Bush and Bantu peoples, while the Strandlooper is further removed from the latter than the Bushmen are.

2. While presenting such intermediate dimensions and indices, the Hottentot shows in many features a small coefficient of variation, indicating that the cross—if such is the correct explanation—is of long standing and complete.

3. In those characters in which the Western Bantu differ from the Eastern they resemble the pygmy stock.

4. The Strandlooper appears to represent a less variable group than the Bushmen, and in all respects is a purer group, the up-country Bushmen being intermediate between the Strandlooper and the Hottentot.

5. (1) Strandlooper is the mesaticephalic (nearer brachycephaly).

    (2) Bush is more dolichocephalic.

    (3) Hottentot is more dolichocephalic.

    (4) Bantu are mostly dolichocephalic : on the West, however, they become mesaticephalic.

The interrelations of these groups will be demonstrated further when we proceed to compare indices and measurements obtained for Bush, Hottentot, Bantu, and European skeletons with the figures yielded by the Griqua skeletons.

Collect. Date.	Collect. No.	Locality.	Particulars.	Catalogue No.
May 1919	A	Devondale Grange	4 ft. Polishing-stone with red-ochre . . .	2
,,	B	,, ,,	3 ft. Skull broken . .	—
,,	C	,, ,,	3 ft. Skull absent, and also cervical vertebrae .	2a
,,	D	,, ,,	6 ft. Skull broken, bones scattered : two ochre-grinders and six siyp-steene in grave . .	
,,	E	,, ,,	6–7 ft. . . .	3
,,	F	,, ,,	2½ ft. Badly broken .	—
,,	G	,, ,,	2½ ft. Bones decaying .	—
,,	H	,, ,,	2½ ft. Bones decayed .	—
,,	I	,, ,,	4 ft. Bones decayed .	3a
,,	J	,, ,,	5½ ft. Beads round neck and arms . . .	4
			Note.—The graves A–J were all filled with boulder to the top, with small monument.	
June 1919	K	Driekop, Riet River	4 ft.	5
,,	L	,, ,,	3 ft.	6
,,	M	,, ,,	4 ft.	7
,,	N	,, ,,	4 ft. Beads round hips and arms . . .	8
			Note.—L, M, N, buried beneath boulders—K, grave filled with soil.	
,,	O	Ramah Manor .	4 ft. Griquas of Adam	9
,,	P	,, ,,	5½ ft. Kok's band, in	10
,,	Q	,, ,,	4 ft. coffins, some iron	11
,,	R	,, ,,	4 ft. bound ; facing N.	12
,,	S	,, ,,	5½ ft. headstone; graves	13
,,	T	,, ,,	5½ ft. filled with soil.	14
,,	U	David's Grafe .	5 ft. Child . .	15
,,	V	Modder River .	5 ft. Coffin . . .	16
,,	W	,, ,, .	5 ft. Coffin . . .	17
,,	X	,, ,, .	5½ ft.	18
,,	Y	,, ,,	3½ ft. Grave lined with stones . . .	19
,,	Z	,, ,,	5½ ft. Coffin . . .	20
Feb. 1918		Driekop, Riet River	3½ ft. Knees and arms drawn up ; clay pot on skull . . .	1a

Probably Bushmen

SECTION VIII.

COMPARATIVE TABLES.

TABLE A.

	West Bantu.	Kaffir.	Hottentot.	Bush.	European.	Griqua.
Leng. ht. ind. .	..	..	..	70·3	72·9	72·2
Alveolar ,, .	..	..	..	10·0	96·2	98·5
Nasal ,, .	..	..	..	60·4	46·0	58·2
Facial ,, .	..	..	.·.	49·2	54·0	50·5
Stephano-zyg.,, .	..	..	..	..	90·7	..
Leng. br. ,, .	..	..	..	75·4	..	76·2
Br. ht. ,, .	..	..	..	..	..	94·8
Orbital ,, .	..	..	..	..	85·5	85·1
Dental ,, .	..	..	..	..	..	..
Maxillo-pal. ,, .	..	..	..	..	..	115·8

The close correspondence between Bush and Griqua is here everywhere evident, the latter being more particularly differentiated from European as regards the nasal and facial indices.

TABLE B.

	Negro.	Kaffir.	Hottentot.	Bush.	European.	Griqua.
Scapular ind. .	69·7	..	60·0	66·1	65·3	73·9
Gen. lumb. ,, .	103·0	..	..	99·5	96·0	99·4
Sacral ,, .	106·0	92·8	82·0	95·3	112·4	92·2
Innom. ,, .	80·7	..	..	70·5	74·5	70·6
Pelvic ,, .	80·0	..	..	89·5	79·0	87·0
Pelvic brim ,, .	90·5	95·0	..	94·7	97·0	92·6
Tibio-fem. ,, .	82·9	81·5	79·3	84·1	80·82	84·2
Radio-hum. ,, .	78·2	78·7	..	78·4	72·3	77·3
Humero-fem. ,, .	71·2	70·1	72·0	71·0	72·5	70·9
Intermembr. ,, .	68·4	69·4	68·6	68·6	79·7	68·2
Upper platymeric ind.	..	..	..	80·3	..	100·1
Lower platymeric ind.	85·0	..	..	68·7	..	67·8
Platycnemic ind. .	105·8	..	..	128·2	109·2	114·3

Here again the similarity is apparent between the Bush and the Griqua, particularly in the pelvic, sacral, innominate, intermembral index and

lower platymeric indices, where the Negroid and European figures are markedly different. In the lower platymeric index some approach to the European is seen, while a somewhat intermediate character is shown in the pelvic-brim index also. In the sacral index the intermediate character between Bush and Hottentot (which is remarked on elsewhere) is evident.

TABLE C.

	West Bantu.	Kaffir.	Hotten-tot.	Bush.	Griqua.	Euro-pean.	Strand-looper.
Glabello - occip. length	179·1	190·6	183·2	178·8	181·5	..	181·2
Max. breadth .	135·8	137·3	133·5	134·7	135·2	..	138·3
Basi-bregmatic .	133·7	137·4	130·6	126·4	136·4	..	126·1
Bi-zygomatic br. .	128·6	134·1	125·8	121·4	126·0	..	123·9
Naso-alveolar ht. .	66·4	69·1	65·5	60·2	65·5	..	61·7
Nasal ht. . .	47·5	48·7	46·2	42·8	46·5	..	43·8
Basi-nasal lgth. .	100·9	105·0	98·3	94·9	98·5	..	93·7
Basi-alveolar lgth.	103·9	105·1	99·6	95·9	97·2	..	90·7
Nasal breadth .	26·8	27·3	26·3	25·9	26·2	..	25·0

The resemblances of the Griqua are here markedly with the Hottentot-Bush races, besides which some of the values found are clearly indicative of a peculiar approach to the Bush, giving an intermediate figure between this and the Hottentot. (As there has arisen some contention as to the ability of investigators to distinguish between the Bush and Hottentot races anthropometrically, we shall not always be able to demarcate them too sharply here—but resemblance to either will, nevertheless, be significant enough of Negrito blood.)

In the basi-bregmatic height, however, the Griqua strongly approaches the Bush-Kaffir, and this gains considerably in interest when we recall the fact that the small altitude and platypellic nature of the Bush skull is one of its outstanding characteristics.

TABLE D.

Measurements according to Thomson and MacIver's new method for prognathism.	West Bantu.	Kaffir.	Hotten-tot.	Bush	Euro-pean.	Griqua.	Strand-looper.
A. Dist. of 1 from nasion .	89·0	93·0	87·0	84·4	..	89·3	83·5
B. ,, ,, ,, prosthion	103·5	103·0	96·9	93·6	..	100·5	88·5
C. Subnasal projection .	14·5	10·9	9·9	9·2	..	7·8	5·0
Index : $\dfrac{c\ 100}{a}$.	16·3	10·7	11·4	10·9	..	8·5	6·0

The actual index here obtained will be the most reliable clue to relation-
ships. Where the distinctness of the Bush and the Hottentot is quite
marked, the Griqua seems here to manifest a similarity to the Strandlooper,
while differing fairly equally from Bush, Kaffir, Bushman, and Hottentot.
The conclusion that this is a case of reversion to an early ancestral trait
seems fairly reasonable here when we remember that the index measures
the subnasal projection. We are safe in concluding that the resemblance is
not actually to the primitive Strandlooper, but to the European, who is
also essentially orthognathous, although the data desired are wanting here.

TABLE E.

	Strand-looper.	Bush.	Hottentot.	East Bantu.	West Bantu.	Griqua.
Cephalic ind. :						
Dolichocephalic .	25·0	45·8	60·0	75·2	32·5	56·25
Brachycephalic .	15·0	4·2	. .	1·7	11·6	6·25
Mesaticephalic .	60·0	50·0	40·0	23·1	55·8	37·5
Altitudinal ind. :						
Chamaecephalic .	88·9	42·3	35·1	28·8	9·1	68·75
Orthocephalic .	11·1	46·2	56·8	40·8	28·6	31·25
Hypsicephalic .	. .	11·5	8·1	30·3	62·3	
Brdth.-ht. ind. :						
Akrocephalic .	50·0	13·4	46·9	80·7	63·6	31·25
Metriocephalic .	50·0	55·8	31·2	19·2	31·2	50·0
Taprinocephalic .	. .	30·8	21·9	. .	5·2	18·75
Alveolar ind. :						
Orthognath. .	60·0	43·2	16·7	20·2	7·5	56·25
Mesognath. .	20·0	36·7	50·0	50·9	43·3	25·0
Prognath. . .	20·0	20·1	33·3	28·9	49·2	18·75
Facial ind. :						
Chamaeprosopic	60·0	47·5	36·8	24·1	27·6	12·5
Leptoprosopic .	40·0	52·5	63·2	75·9	72·4	87·5
Nasal ind. :						
Leptorhine .	. .	3·3	. .	1·7	1·3	6·25
Mesorhine .	13·3	13·3	25·0	18·9	20·3	18·75
Platyrhine .	86·7	83·3	75·0	79·4	78·9	75·0
Orbital ind. :						
Megasome .	70·5	17·8	34·3	40·3	38·3	37·5
Mesosome .	23·5	44·6	31·4	34·0	41·1	6·25
Microsome .	59·0	37·3	34·3	25·9	21·6	56·25

Once again the affinities of the Griqua are shown to be strongly with
the Negritos, except as regards the variation of the facial index, where

they are decidedly with the Eastern Bantu, as far as we can judge in the absence of European data, which would probably explain the peculiar features of the orbital index also.

ANTHROPOMETRICAL RESULTS AND THEIR CORRELATION.

One of the first criticisms which might reasonably be levelled against the value of the results of this investigation concerns the apparent impossibility of determining whether the material investigated represents " pure or impure " Griqua remains or not. This difficulty was appreciated at the beginning of the work, and, consequently, in the collecting of the material every care was taken to ensure the *bona fide* nature of the same by investigating the nature and circumstances of burial and the history of the community, etc. Such evidence is, of course, by no means final, and it would be unscientific to accept it as such. We realised, however, that the value of the results would be enhanced if as large a number of skeletons as possible were collected in a community which the above-mentioned evidence strongly suggested as being Griqua, and the average measurements bore out the same character. Although only twenty skeletons have been investigated, we consider that the history of the burials and measurements of the material as graphed indicate conclusively that we have been dealing with genuine Griqua remains. A cursory glance at the skulls carries the impression that they are somewhat heterogeneous, but bear resemblance superficially to the Bantu or European rather than to the Bush race. The variation of the skulls in respect of length-height, length-breadth, and alveolar indices is represented on a percentage basis in graphic form in figs. 6, 7, and 8. In the same figures the variations in the skulls of Bush-Strandlooper stock, as recorded, has been superimposed, and it is readily indicated that the material investigated is much the more uniform. An examination of the graphs shown in figs. 1 and 3 reveals a closer approach to the Bushman-Hottentot stock and in most cranial measurements a general parallelism, with, however, distinct points of deviation towards a type much higher than Hottentot or Bushman. The presence of a factor distinct from and superior to Bushman and Hottentot is conclusively shown in fig. 1.

The cranial indices indicate clearly a higher cranial capacity for the Griqua skull than for the Bushman, and, generally speaking, a lower capacity than for the Hottentot. In fact, in respect to this measurement and the other indices, except the basi-bregmatic height, the Griqua skull might be regarded as a blend between the Bushman and Hottentot skulls. It is noteworthy that a corresponding conclusion obtains in respect of the relation of the Hottentot to the Bushman and the Bantu respectively. The
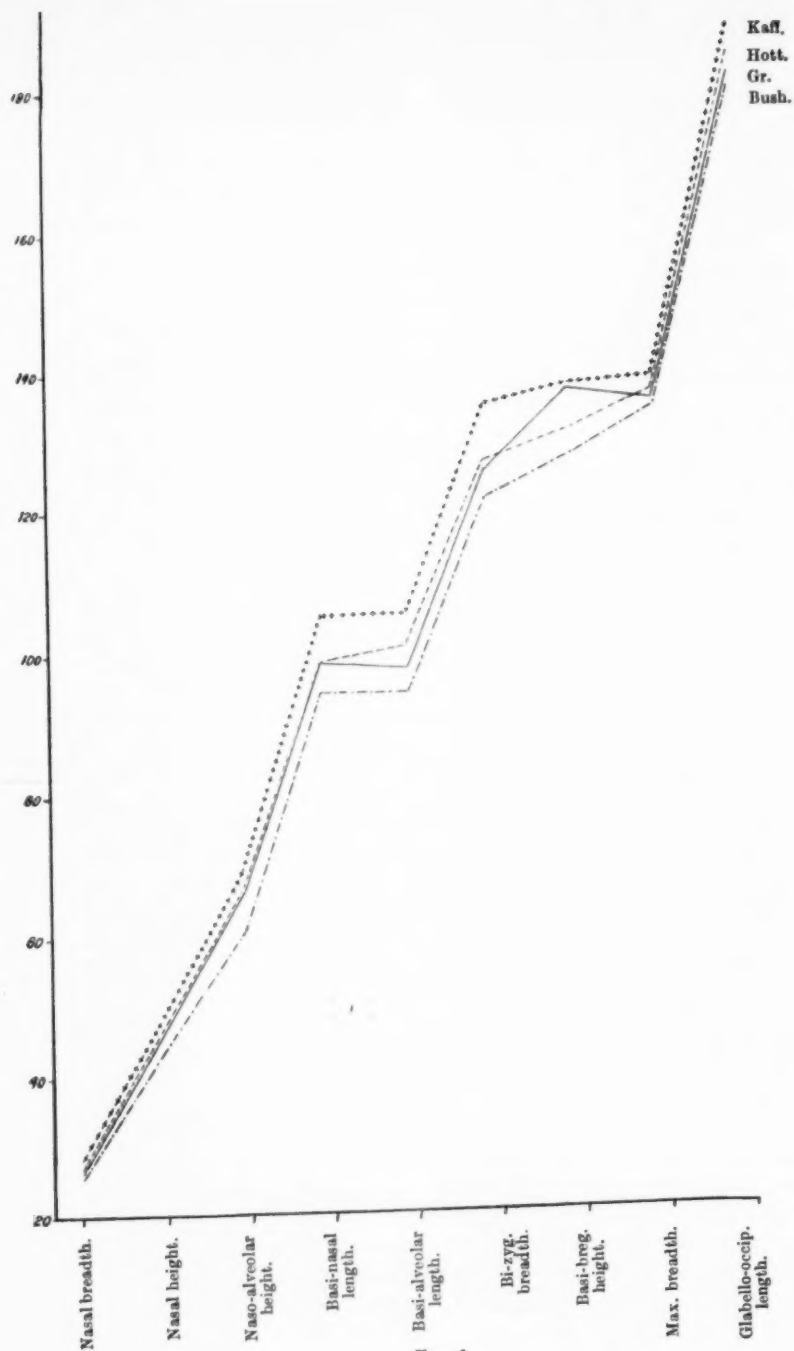
FIG. 1.
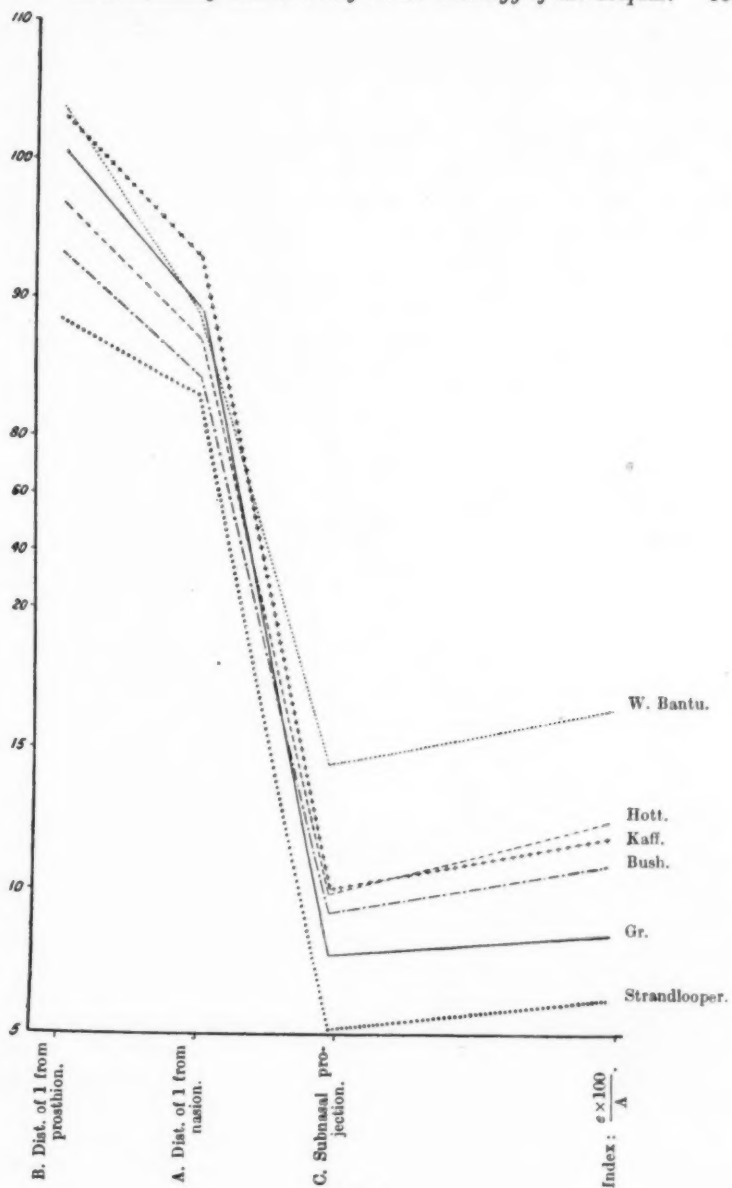
FIG. 2.

components concerned in the origin of the Hottentot are asserted by anthropologists to be three, viz. Bushman, Bantu, and Hamitic. There can be
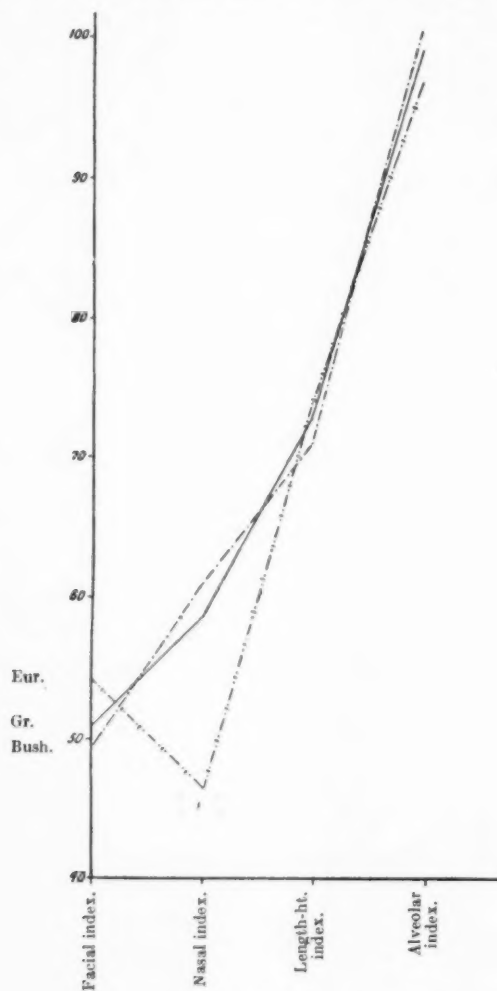
Fig. 3.

no doubt that the cranial measurements of the Hottentot indicate an admixture of the Bushman with higher stock, but the extent to which it is

possible to differentiate between the relative effects of Bantu and Hamitic elements in giving to the Hottentot skull its characteristic features cannot be determined in the absence of data concerning the Hamitic element. All that we can remark on at this stage concerns the intermediate character of the Hottentot skull in relation to the Bantu and Bushman. This has some bearing on the question as to what extent we can unravel the history of the Griqua from a study of the skull and other parts of the skeleton. We have already remarked on the blend-like relation to the Bushman and
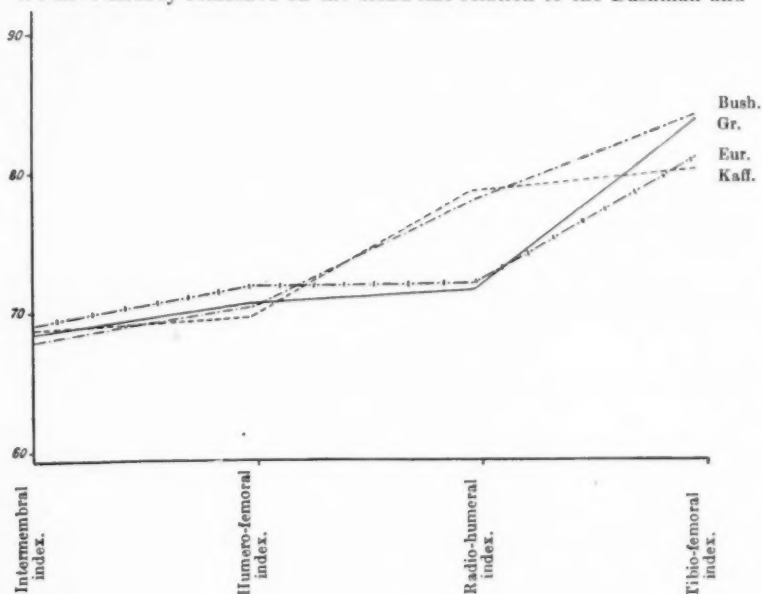
Fig. 4.

Hottentot in respect of most cranial features, but have drawn attention to the remarkable deviation in connection with the basi-bregmatic height, and the necessary conclusion that the presence of some higher element is thereby indicated. The question now arises, " Is this higher element Bantu or European ? " This requires very careful consideration. In the skulls under consideration the following possible components might be critically suggested, with a view to analysis of each in the light of the measurements made :—

(*a*) Bushman and Hottentot.   (*d*) Hottentot and Bantu.

(*b*) Bushman and Bantu.   (*e*) Hottentot and European.

(*c*) Bushman and European.

Bushman-Hottentot Origin.

Much can be said in favour of this in respect of such indices as nasal breadth, nasal height, naso-alveolar height, basi-nasal length, basi-alveolar length, bizygomatic breadth, maximum breadth, etc., but against this is the insuperable difficulty presented by the basi-bregmatic height, and, to refer to
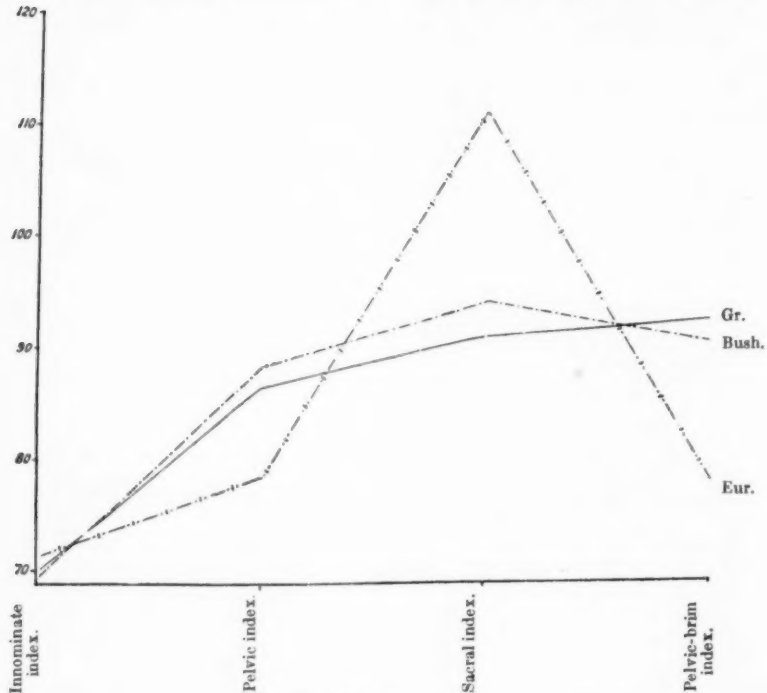
Fig. 5.

another part of the skeleton, the radio-humeral index. Other features might be mentioned, but at this stage, awaiting a complete set of comparative data at present unavailable, we focus attention on the two indices specially mentioned, because they are most significant. The basi-bregmatic index would seem to be conclusive evidence against the adoption of this origin. We must, however, bear in mind that it might be suggested that this index is possibly to be explained as a result of the assertion of a potentiality intrinsically due to the presence of a higher element—Bantu or Hamitic—under the influence of some stimulus too subtle to be detected. Such is,

however, very improbable. That such is so is suggested by the radio-humeral index. An examination of fig. 4 shows that whereas in respect
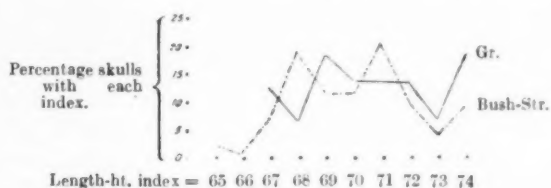
Fig. 6.

of this index the Bushman and Bantu (Kaffir)—and also the Hottentot—approximate, in the Griqua material examined there is a marked divergence
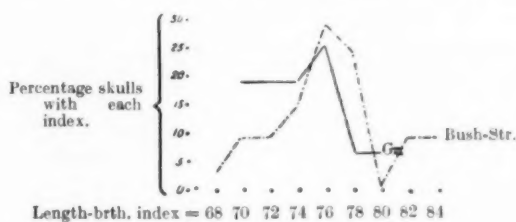
Fig. 7.

from them and a very close approximation to the European. This may reasonably be construed as signifying that the higher element entering
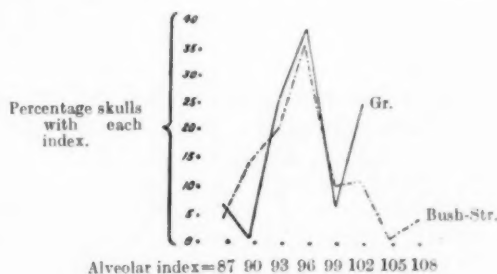
Fig. 8.

into the Griqua material is European and not Bantu, and that this is the true explanation of the strong basi-bregmatic index.

12

Bushman-Bantu Origin.

Bushman-Bantu components as the only factors entering into the composition of the Griqua cannot explain the two indices specially mentioned above, and this origin cannot be entertained. Further, were such the case we might expect the appearance of the same basi-bregmatic index in the Hottentot, even if not more marked still, owing to the suggested presence of Hamitic elements in the Hottentot.

Hottentot-Bantu Origin.

Much more could be said in favour of this origin than of the two preceding. It might very reasonably be suggested that the basi-bregmatic index could be attributed to the Bantu element, but we still encounter an insuperable difficulty in respect of the radio-humeral index.

Bushman-European Origin.   Hottentot-European Origin.

It seems to us that the elements entering into the material examined by us are either Bushman and European or Hottentot and European. It appears from the data accessible to us that it is impossible from the skeletons alone to definitely suggest one of these to the exclusion of the other. We do not consider that such would be impossible were comparative data available.

We believe that we are justified in regarding this material as genuine Griqua stock, and in appealing to history there is every reason to suggest that the elements concerned are Hottentot and European. Although the distinction between Hottentot and Bushman is by no means as easily made as most people imagine where external features are concerned, yet it can with more certainty be made when skeletal features are considered. In this connection we have already referred to the " blended " nature of the Hottentot skull in relation' to the Bushman and Bantu skulls. The cranial measurements are beautifully intermediate, but the external features are unilateral or preponderant in favour of the Bushman. How old the Hottentot stock is we cannot tell, but we do know that it was isolated for a considerable time, that there was an exclusive inbreeding, and that it had become a fixed or true-breeding stock, a fact of considerable interest in connection with the problem of bastardisation.

If now we regard the material under investigation as containing Hottentot and European elements, we meet with some interesting facts. In respect of most of the cranial indices we find not an intermediate or " blended " condition between Hottentot and European, but instead a reversion or

atavistic condition in favour of the Bushman ancestry. At the same time there is a particulate inheritance in respect of the basi-bregmatic and radio-humeral indices in favour of the European ancestry. The explanation of this is possibly to be found in the pureness, or, in other words, the age and fixedness of the Bushman and European stocks in contrast to the Hottentot stock. This might well have been expected, as many parallel cases, or what have been suggested as parallel cases, have been brought to light in anthropological investigations concerned with prehistoric migrations.

The problem does not lose interest on the suggestion being made that the elemental factors are Bushman and European. Here again we meet not with a true intermediate blend, but in respect of most characters " lagging " in favour of the Bushman element and a particulate inheritance in favour of the European in respect of the two significant indices discussed above. It would be a most interesting fact that Bushman and Bantu components produce a true blend, whereas Bushman and European elements produce a stock partly atavistic and particulate, a result quite in keeping with the riddles of inheritance. However, we have no reason to suggest this origin.

The line of research opened up in this investigation appears to offer much interesting information as bearing on problems of inheritance and variation. The first requirement is a complete set of comparative data. In this connection data, bearing on the vertebral columns of the various elements should be of very great value. Figs. 2 and 5 are very suggestive, and might be construed as indicating a composite character for the Bushman, thus upholding the commonly accepted relationship of that stock to a more primitive stock—the Strandlooper. In this way we can get some explanation of the Griqua indices falling in respect of some measurements between those of the Bushman and the Strandlooper. Another suggestion would be to regard these deviations as mere variations. The settlement of this question can only be effected with the help of full statistics.

In conclusion, it may be stated that the results of this work tend to support and lend credence to the work of anthropologists and the methods adopted by them in attempting to unravel the history of prehistoric man and prehistoric migrations.

Some Abnormalities in the Griqua Skeletons.

The chief abnormal features in the eighteen Griqua skeletons were :—

(a) In Nos. 17 and 18 sacrodorsal vertebrae were found.

(b) In Nos. 17 and 7 an extra lumbar vertebra was found, making

twenty-five segments in the movable column, without any correspondent reduction in the sacral segments.

(*c*) In No. 7 the 2nd, 3rd, and 4th cervical vertebrae were ankylosed by synostosis : the specimen was undoubtedly that of an aged individual, however, and the condition may have been pathological.

(*d*) In No. 8 the 4th and 5th lumbars were united by ossification of the subdorsal ligaments.

(*e*) Pilastering of the femora was evident in Nos. 2, 4, and 5, the lower index of platymeria being 138, 116, and 119 respectively.

Topinard has found that in rickety subjects an average of 111 is found, as compared to an average of 109 for the normal French type, so that the high degree of pilastering here could scarcely be taken to be due to rickets.

(*f*) In Nos. 4, 8, 16, and 18 the sacrum consisted of six vertebrae.

The frequent presence of abnormal features is surprising, particularly such a condition as the supernumerary lumbar vertebra, which Cunningham found in about 5 per cent. of European skeletons examined, and which occurs here in 16 per cent. of the individuals.

APPENDIX.

Note on Two Bushman Skulls.

Two skulls, apparently of Bush race, were disinterred at " Devondale," Dist. Herbert. The graves, numbering a dozen or more, were situated in a low valley between rugged kopjes on which several pteroglyphs were found : most of the skeletons were irretrievably damaged, however, apparently due to the careless throwing of large stones on the bodies to fill the graves. The skeletons were often in a sitting attitude or on their sides—sometimes not.

As the two skulls were obtained during my collecting for research on the Griquas, I am adding this brief account of them to my report.

MEASUREMENTS ON TWO BUSH SKULLS.

	Glabello-occipital Length.	Maximum Breadth.	Bi-zygomatic Breadth.	Bi-auricular Breadth.	Bi-stephanic Breadth.	Bi-asterionic Breadth.	Basi-bregmatic Height.	Basi-nasal Length.	Basi-alveolar Length.	Bi-dacryic Breadth.
Bush.—No. 2 .	182	139	128	117	117	110	126	95	93	22
Bush.—No. 3 .	177	127	129	112	110	111	119	85	83	23

	Naso-alveolar Height.	Nasal Height.	Nasal Breadth.	Internal Bi-orbital Breadth.	Palato-max. Length.	Palato-max. Breadth.	Right Orbital Breadth.	Right Orbital Height.	Left Orbital Breadth.	Left Orbital Height.
Bush.—No. 2 .	59	44	25	99	53	55 ?	39	31	40	31
Bush.—No. 3 .	59	41	25	99	48	..	38	30	38	32·5

	Naso-malar Curve.	Frontal Curve.	Parietal Curve.	Occipital Curve.	Total Sagittal Curve.	Total Horizontal Curve.	Total Coronal bi-auricular Curve.			
Bush.—No. 2 .	..	129	126	112	367	499	300			
Bush.—No. 3 .	..	127	113	121	361	499	283			

DETERMINATION OF DIRECT SUBNASAL PROJECTION (THOMSON AND MacIVER).

	(1) Dist. of 1 from Nasion.	(11) Dist. of 1 from Alveolar Point.	(111) Subnasal Prognathism.	$\dfrac{(111) \times 100}{(1)}$
Bush.—No. 2 .	85	91	6	
Bush.—No. 3 .	76	80	4	

	Length-Breadth Index.	Length-Height Index.	Breadth-Height Index.	Kollmann's Upper Facial Index.	Maxillo-palatine Index.	Average Orbital Index.	Nasal Index.	Alveolar Index.	Dental Index.	Naso-malar Index.
Bush.—No. 2 .	76·4	69·2	90·7	46·1	104 ?	78·5	56·7	97·9		
Bush.—No. 3 .	71·7	67·2	93·7	45·7	..	82·2	60·9	99·6		

	Total Facial Height.	Bi-condyloid Breadth.	Maximum Bi-gonial Breadth.	Symphysial Height.	Malar Height.	Condylo-coronoid Breadth.	Maximum Bi-gonial Curve.	Ramus Breadth.		
Bush.—No. 2 .	97 ?	113	97	30	24	35	199	47		
Bush.—No. 3 .	100	..	..	33	24	40	..	51		
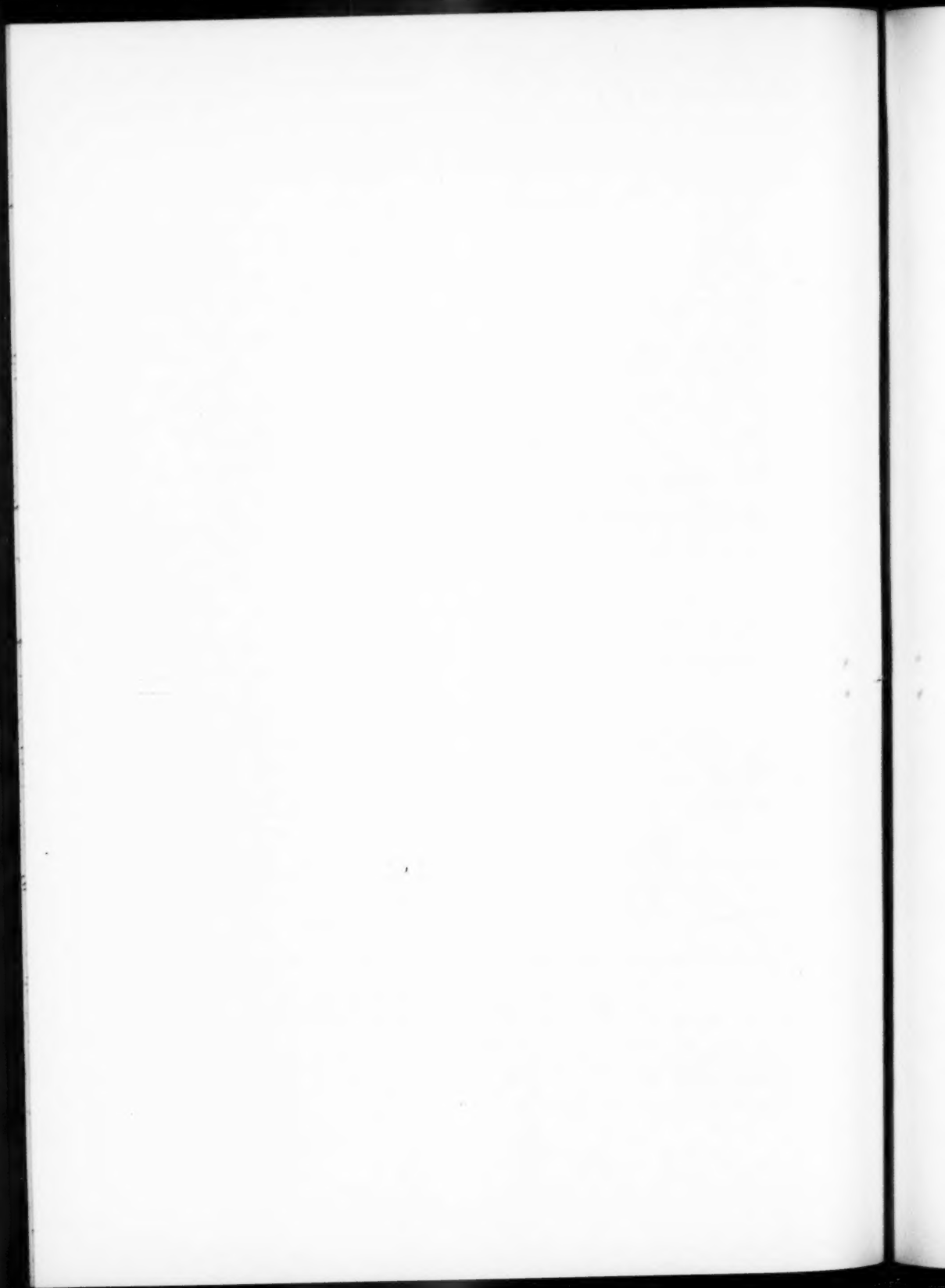
HOLTZHUISBAAKEN SPRING, CRADOCK.

By Thomas Stewart, M.Inst.C.E., F.G.S.

The spring discussed in the following paper is a typical Karroo spring. It is the source from which the town of Cradock obtains its supply of water for domestic purposes, and it is because of this fact that certain of its characteristics have received considerable attention. For instance, measurements of the flow have been taken over a period of thirty-eight years, and although there are several breaks in the continuity of the observations, they nevertheless constitute the most extensive record that exists of the yield of a Karroo spring. The writer is therefore of opinion that this unique record is worthy of insertion in the Transactions of the Society.

The spring rises on a farm called Holtzhuisbaaken, about 10 miles north-east of the town, and about 7 miles east of the Fish River. Its elevation above sea-level is about 3630 feet, and above the Fish River directly to the west about 750 feet. Its height above the town (the floor of the D. R. Church) is 756 feet.

The topography of the surrounding country is hilly and broken, the prevailing features being narrow valleys separated by well-defined ridges. The floors of the valleys consist nearly always of shales and finely grained sandstones belonging to the Karroo series of rocks, and the ridges of dolerite. The bottoms of the valleys are overlaid by alluvium of variable thickness, and the slopes are covered by boulders and smaller debris derived from the weathering of the dolerite rocks.

The spring appears at the surface, escaping through beds of fine-grained sandstone in a dry river bed. The cause of its occurrence is a dolerite dyke which crosses the valley about 300 yards farther down than the spring. The sedimentary rocks which intervene between the spring and the dyke have been highly metamorphosed by the dyke, and are often flinty in character. Apparently the metamorphosed strata have been rendered impervious, otherwise the spring would have occurred nearer the dyke, as there is a fall of about 21 feet between the spring and the lowest part of the dyke.

The catchment area above the spring extends to about 14 square miles, according to information which has been supplied to the writer.

The width of the valley at the spring is about 200 yards, but it increases as it spreads southward from the spring. At about a mile from the spring it branches into two, one branch being considerably longer than the other, and much flatter. The slope of the valley at the spring is about 130 feet per mile.

The writer first became acquainted with the spring in October 1884, while he was engaged in investigating the question of finding a suitable supply of water for the town of Cradock. At the time the district was suffering from a drought, the rainfall for the previous twelve months having been only 10·50 inches, and for the previous twenty-four months 24·45 inches.

The first gauging of the spring was made on the 30th of October 1884, and gave 65,000 gallons per 24 hours. On the 20th of November following the flow was practically the same. In June 1885 it had risen to 86,000 gallons.

The gaugings made previous to the year 1887 were made by the writer, but since 1887 they have been made by the Superintendent of the water-works, and forwarded to the writer by the Town-Clerk, Mr. B. A. Paterson.

There are no rain gauges, so far as the writer is aware, within the catchment area which feeds the spring; so the only rainfall statistics which can be regarded as more or less applicable are those observed at the town. These, however, must be dealt with cautiously, because the rainfall, like all rainfall in the Karroo, is erratic in its distribution, that is, there may be a heavy fall of rain on one farm, while on the adjoining one there may be none. However, an examination of the records shows that, taking the whole of the seasonal rainfall, its effect is reflected in the flow of the spring.

According to the reports of the Meteorological Commission, rainfall data for the town of Cradock are available from the year 1881. The distribution of the average rainfall throughout the year is shown in the following tabulation and diagram. The figures denote inches of rainfall.

Monthly Averages for 42 Years.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
2·11	2·39	2·18	1·40	·85	·48	·27	·39	·71	1·01	1·24	1·41	14·44
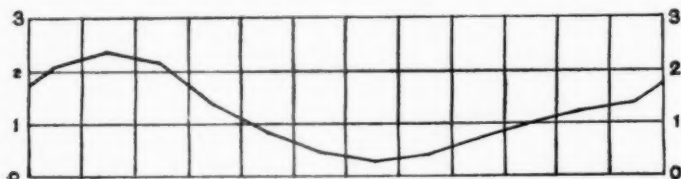
According to these figures for rainfall, the year should be divided into two periods : a " wet " period consisting of the months October to April, and a " dry " period consisting of the months May to September.   This division is supported by the temperature, which is approximately the same for the months of October and April.   As these periods correspond respectively to the hot or summer season and the cold or winter season, the terms will be considered as synonymous.   It will be seen that 81·3 per cent. of the annual rainfall occurs during the seven warm months, April to October, and 18·7 per cent. during the five cold months.   The three months, January to March, are responsible for about 46 per cent. of the year's rainfall.

The average annual rainfall amounts to 14·44 inches.   There are, however, large divergencies, the maximum having reached 26·81 inches (in 1891), while the minimum has been as low as 4·11 inches (in 1919).

A table is appended showing the monthly rainfall and the gaugings of the spring from 1881 to December 1922.   It is evident from a cursory glance at this table that the discharge of the spring fluctuates according to the rainfall, becoming high after seasons of heavy rainfall and low after seasons of low rainfall, but the closeness of the relationship is not always apparent from the table.   I propose, therefore, to give some instances where the direct effect of the rainfall is clearly reflected in the gaugings.

Taking the most striking results it will be seen that the maximum flow recorded is 334,080 gallons per 24 hours, and the minimum 25,792 gallons per 24 hours.   The former occurred on the 1st of May 1890, and the latter on the 14th February 1917.

The amount of rain which fell during the period while the flow of the spring was increasing to the maximum, and the rate of increase in the flow is shown in the following tabulation :—

	Rainfall. Inches.	Flow of spring. Gallons per 24 hours.	Date of gauging.
1889 Oct.	2·76	81,400	10th Oct.
Nov.	3·13	90,000	10th Nov.
Dec.	4·00	143,000	23rd Dec.
1890 Jan.	4·35	194,000	10th Jan.
Feb.	3·00	252,000	30th Jan.
Mar.	1·39	295,000	13th Mar.
		334,000	1st May
Total	18·63		

The rainfall for April 1890 was 2·19 inches, but, as will be shown later, it is improbable that it affected the flow of the spring as measured on the 1st May, so it is left out.

The total rainfall for the above six months is the greatest recorded for any consecutive six months, but that for the same months of 1900–1901 is only 0·75 inch less.   Unfortunately no gaugings of the spring were taken during the latter period.

There is a break in the records from May 1890 to January 1895, because apparently the taking of gaugings was not regarded as of so much importance in times of plenty as in times of scarcity.

From January 1895 to February 1897 the gaugings taken were few and the periods between them irregular.   The flow, however, on the occasions when it was measured was abundant, being always well above 100,000 gallons a day.

Between February 1897 and May 1903 no gaugings were taken, but in the latter month one was taken, which showed that the yield had decreased to 69,000 gallons a day.   This yield was maintained in June, but it fell gradually thereafter till in the following February (1904) the amount was only 45,560 gallons per 24 hours, which is the lowest flow recorded up to that date.   The cause is very evident.   In only one month of the year 1903 did the rainfall reach the average, and the total for the year amounted to only 7 inches, which is not quite half the average.   It was also the lowest annual rainfall since observations began in 1881.

From February the yield gradually increased until it reached 80,000 gallons per day in June.   No gaugings appear to have been taken for a year thereafter.   When taken on the 30th of June 1905, the flow was found to have fallen to 45,000 gallons a day, being the lowest yield observed so far, although very little below that of February 1904.   The rainfall for the previous summer had again been deficient, amounting to only 5·30 inches for the six months.

September 1905 received a large rainfall, in all 3·05 inches.   It was clearly beneficial to the spring, because although the rainfall for the two following months was much below the average, the flow of the spring did not diminish, but, on the contrary, it continued to increase from 51,800 gallons on the 10th September to 55,700 gallons per day on the 15th December.

The measurements of the spring for the whole of the ten months following June 1905 were comparatively low, the highest amounting to only 70,100 gallons per 24 hours, which was found on the 30th April 1906.   May, however, gave a rate of 93,100 gallons, but by the 4th of December this had fallen to 83,500 gallons per 24 hours.   This state of things is shown in the following tabulation : —

Total rainfall for period of twelve months ending two months previous to taking of gauging.	Rainfall for seven summer months previous to taking of gauging (average 11·74 inches).	Yield of spring. Gallons per 24 hours.	Date when gauging was taken.
7·44 inches ⎫ 8·66 ,, ⎬ 12·84 ,, ⎭ 14·47 ,, ⎫ 11·05 ,, ⎭	7·07 inches 8·40 inches	⎧ 45,000 ⎩ 51,700 ⎧ 70,100 ⎨ 93,100 ⎩ 83,500	30/6/05 8/8/05 30/4/06 29/5/06 4/12/06

It will be seen that the whole of the first twelve months was deficient in rainfall, the summer months being particularly so.

The flow of the spring increased during the six weeks between the 4th December 1906 and the 16th January 1907 from 83,500 gallons to 154,000 gallons per 24 hours, or nearly double. This increase is accounted for by the heavy rains which fell during the three months, September, October, and November of 1906; for these three months the total rainfall was 8·89 inches, as compared with the average of 2·96 inches. No doubt the increase in the flow of the spring began before the date of the gauging in January, but there is no gauging to show it.

No measurements of the spring appear to have been taken between January 1907 and April 1908; when taken the yield was found to have decreased to 80,000 gallons a day. Five months later (*i.e.* in the following September) it had decreased to 45,000 gallons a day. This was the third occasion since gauging was begun in 1884 that the flow had been found to be below 46,000 gallons a day. On this occasion the small yield is accounted for by the low rainfall for the six months, February to July, which totalled only 3·51 inches, compared with the average of 7·57 inches.

At the beginning of January 1909 the flow was still the same, but it rose rapidly thereafter till it reached 209,520 gallons a day in June. The total rainfall for the five months, January to May inclusive, was 15·12 inches (compared with the average of 8·93 inches), so the cause of the increase is plain.

The remaining gaugings for 1909, and those taken in 1910 and 1911 do not exhibit any striking points.

During 1912, however, the seasonal distribution of the rainfall was much disturbed. The total for January, February, and March was only 3·13 inches (average 6·68 inches), while April alone gave 3·29 inches (average 1·40 inches). May, June, and July gave about the average rainfall, but September, October, and November gave nothing at all. The amount for

December was only ·40 inch, which is negligible as far as the spring is concerned.

The total rainfall for the year was therefore 8·37 inches, or 57·9 per cent. of the average. The flow of the spring fell from 93,120 gallons per day in January 1912 to 42,000 gallons in January 1913, and notwithstanding an average rainfall for January, February, and March the yield decreased to 40,000 gallons a day. This was the lowest measurement recorded up to that date, and it followed upon a year of very deficient rainfall.

The years 1913 and 1914 received about average rainfalls, and as these were fairly distributed throughout the summer season, the yield of the spring never rose to an abnormal height; the greatest flow was 83,000 gallons a day, which occurred in July and August 1914.

December 1914 may be said to mark the beginning of the severest drought which the district had known since observations of the rainfall began. Only ·69 inch of rain fell during this month, and from January to September of 1915 inclusive the total rainfall was only 7·44 inches, or about 69 per cent. of the average, and the rains were light. The consequence was that the yield of the spring on the 15th of the latter month was found to have fallen to about 36,190 gallons per day. The rains for October and November were negligible, so the yield of the spring fell to 33,080 gallons per day in December. The rainfall for December was slightly above the average, but that for the summer of 1915–1916 was much below it, and the total for the nine months, January to September 1916, was only 7·15 inches.

The effect of the continued drought is reflected in the yield of the spring, which fell to 29,337 gallons per day on the 15th of October. This is the second lowest gauging ever recorded.

The rainfall for September was ·45 inch and for October 2·09 inches. These rains were apparently the cause of the spring rising to 46,560 gallons a day on the 11th November, but as there was hardly any rain in November the yield decreased again to 29,337 gallons a day in December. The rainfalls for December and January were below the average, and according to the returns the separate falls were small; they were therefore of little assistance to the spring, which on the 14th February 1917 fell to 25,792 gallons per 24 hours, which is the lowest gauging ever recorded.

A comparison of the figures for the years 1917 to 1919 brings some interesting facts to light.

The year 1917 was one of abundant rainfall (total 19·56 inches, or about 35 per cent. above the average). The first three months gave splendid rains— 10·27 inches—but they had very little effect on the flow of the spring. Only once during the year did the flow rise over 100,000 gallons per 24 hours, then it rapidly dropped again. The average discharge of the spring for this year was about 56,000 gallons per day only.

The following year also enjoyed an abundant rainfall, though less than 1917, the total being 16·10 inches. The first three months' rainfall totalled 9·20 inches (more than an inch less than the rainfall for the corresponding three months of the previous year), yet in this case the discharge of the spring rose rapidly to the second highest figure recorded, and the flow remained high throughout the year. The average discharge for this year was about 158,000 gallons per day, or nearly three times that of the preceding year.

The cause of these fluctuations is not difficult to find. The portion of the good rains of 1917 which went underground had to raise the level of saturation so as to make good the deficiency in storage created by the two preceding years of deficient rainfall. This deficiency having been made good, the rains which fell in 1918 were promptly reflected in the flow of the spring.

The following year—1919—had the lowest rainfall on record (4·11 inches); yet the average daily discharge of the spring for the year was about 66,000 gallons, or 10,000 gallons higher than the year 1917, which had a rainfall of 19·56 inches.

This result is entirely due to the two preceding years of good rainfall; the balance of the 1918 rainfall still helping the flow of the spring in 1919.

It will therefore be seen that although the rainfall of a particular season is reflected in the flow of the spring, the amount is not necessarily proportional to it. Regard must be had as well to the rainfalls of previous seasons, and the " tail " of the flow produced by them.

The time taken by the rain which fell in a particular month to affect the flow of the spring can only be arrived at roughly by an examination of the tables of rainfall and spring gaugings, so the writer has endeavoured to get at a closer approximation in certain cases by comparing individual rains with distinct increases in the flow of the spring. Even in these cases, however, the approximation is liable to be wide, because of the length of the intervals between the taking of gaugings of the spring, and also because of the rains which succeeded the first.

In the tabulation on p. 178, therefore, the rainfalls stated should not be regarded as providing the whole of the increases in the spring which follow, as succeeding rainfalls must have overtaken the first on several occasions and added to its effect on the spring.

The following are some examples showing the length of time for which good rains continue to affect the flow of the spring, *i.e.* the length of time taken for the effect of a good rain to pass off, when no contributory rains have fallen in the interim.

In June 1904 the gauging of the spring registered a flow of 209,520 gallons per 24 hours. For six months practically no rain fell (only 1·02

Gauging of spring before being affected by rainfall.	Rainfall.	First gauging of spring after being affected by rainfall.	Time between rainfall and taking of gauging.
Gallons per 24 hours.	Inches.	Gallons per 24 hours.	
16/2/04	24–26/1/04	15/3/04	
45,560	2·92	55,000	7 weeks.
4/12/06	9 and 21/11/06	16/1/07	
83,500	1·05 and 1·91	154,000	8–10 weeks.
13/2/10	28/2 and 1/3/10	8/4/10	
74,794	1·05 and 1·25	119,725	5–6 weeks.
13/4/12	7 and 25/4/12	27/5/12	
69,800	·98 and 1·96	79,840	5–7 weeks.
–/5/19	–/4/19	14/6/19	
68,000	2·14	68,883	About 2 months.

inches all told), yet at the end of the year the flow was still nearly 90,000 gallons per 24 hours, which is a higher discharge than was ever recorded during the five years, 1912–1916.

The gauging for May 1918 gave 239,451 gallons per day.   For five consecutive months the rainfall never reached 1 inch per month, and yet on the 15th September the flow of the spring was still high, namely, 146,176 gallons per 24 hours.

In May 1919 the flow of the spring was gauged as 68,000 gallons per 24 hours.   From May to October inclusive less than a quarter of an inch fell during the whole of the six months, yet the flow of the spring at the end of the year was still 39,000 gallons per 24 hours, which is more than 13,000 gallons higher than the minimum flow recorded.

In June 1920 the gauging registered 193,224 gallons per 24 hours. During the six months, June to November inclusive, the rains that fell were entirely negligible, but in December the flow had only decreased to 119,725 gallons per 24 hours.

Turning now to the important question of the relations of the discharge of the spring to the quantity of water estimated to have fallen on the catchment area ; it is unfortunate that precise information regarding the rainfall on the catchment area is not available, but judging by the flow of the spring, the rainfall observed at the town is a fair indication of that on the catchment of the spring, so the writer has adopted it.   It must, however, be borne in mind that there have doubtless been many occasions

when the rainfalls have differed both in amounts and in the times when they occurred.

In arriving at the relation of the yield of the spring to the volume of rainfall which is estimated to have fallen on the catchment area, certain periods have been taken when the yield at the end of the period has been approximately the same as at the beginning, and the rainfall applicable has been taken as beginning six weeks to two months before the first gauging of the spring for the period was made, and ending two months previous to the taking of the last gauging for the period. It is on this basis that the following tabulation is made :—

Period.	Months.	Rainfall.		Discharge of spring.	
		As observed at the town. Inches.	Estimated volume on catchment area of 14 square miles. Gallons.	Gallons.	Percentage of rainfall.
Dec. 1908 to July 1912.	44	60·01	12,182,030,000	146,486,220	1·20
Dec. 1912 to Aug. 1915.	33	36·64	7,437,920,000	59,526,000	·80
Nov. 1915 to Dec. 1916.	14	12·31	2,498,930,000	16,501,600	·66
Jan. 1917 to Dec. 1919.	36	39·77	8,073,310,000	102,015,530	1·26
Jan. 1920 to June 1922.	30	33·66	6,832,980,000	123,757,540	1·81

The average yield of the spring for the whole of the above period is 1·21 per cent. of the rainfall, that is, of every inch of rainfall which is assumed to have fallen on the catchment area only ·012 reached the spring, but the percentage varies greatly.

The relation of the discharge of the spring to the total amount of rainfall shows that the former diminishes in a greater percentage than the rainfall itself. This is shown in a striking manner by the following instance :—The five years, 1907 to 1911, gave a total rainfall of 74·5 inches, which caused the spring to yield an average flow of about 111,300 gallons a day, but the five years following, 1912 to 1916, gave a rainfall of only

57·5 inches, from which the yield was about 56,800 gallons a day. The diminution in the total rainfall was therefore only 23 per cent., but that in the flow of the spring was 49 per cent.

The percentage difference varies, of course, according to the state of saturation of the ground, but nevertheless the decrease in the flow of the spring is always greater than the decrease in the rainfall.

The average yields of the spring for the five-yearly periods stated above are not quite correct, because, as already pointed out, the effect of the rainfall for the last year of a period may not be fully developed until well on into the first year of the succeeding period. Bearing in mind, however, that the rainfall in the catchment area may on occasions be quite different from that at the town of Cradock, it is hardly worth while to attempt to allocate the proportions of the flow of the spring to the years to which they properly belong.

A consideration of the facts and figures contained in the foregoing pages and in the appendix enables some general conclusions to be arrived at.   They may be summarised briefly as follows :—

As regards rainfall the year may be divided into seven " wet " months and five " dry " months.

The flow of the spring is intimately connected with the seasonal rainfall.

The spring shows the effect of individual rains of considerable amount— say, between $1\frac{1}{2}$ inches and 3 inches—within five to eight weeks after the rain has fallen, and the maximum effect in from three to twelve weeks after the cessation of the seasonal rainfall. The shorter periods occur when the flow of the spring before the setting in of the seasonal rainfall has been high, as well as the rainfall itself, and the longer periods when the conditions have been the reverse.

The variations which occur are also no doubt partly due to several well-known causes, namely, the rate at which the rain has fallen, the temperature and humidity of the air, and the state of the surface soil as regards dryness.

As the bulk of the rainfall occurs in the warm season, and as it takes some weeks to reach the spring, the maximum yield of the spring naturally occurs in the following cold season.

The ready response which the spring makes to heavy rains, and the large fluctuations in the flow—the maximum daily flow recorded being thirteen times as much as the minimum—show that the spring is not what is generally known as deep-seated. The geology of the catchment area and the behaviour of the spring support this conclusion, and indicate that instead of the rainfall penetrating to great depths underground after it has passed through the soil and the broken and fissured rock below it, it

drains down the incline of the surface of the valley until it reaches the neighbourhood of the dolerite dyke, where its further progress is stopped, and the water finds its way to the surface through joints and fissures in the strata.

The percentage of the rain to reach the spring is small, but as there are no data available regarding the flow of a similar spring, so far as the writer is aware, it is impossible to make a comparison of their yields.

That the percentage diminution in the flow of the spring should be greater than the percentage diminution in the rainfall is in accordance with theory, and the same feature is being constantly exemplified by the run-off from surface areas. The amount of the difference varies of course. However, the example of the case of the five-years' period of 1907–1911 receives a curious corroboration if a comparison is made of the relationship of the lowest and highest annual rainfalls with the lowest and highest gaugings of the spring. The former is 15 per cent. while the latter is only 7 per cent., that is about half, which is about the same relation to the rainfall as in the example cited.

By comparing the rainfall and the flow of the spring in previous seasons with the rainfall and the state of the spring in a current season it is possible, assuming that the rainfall during the interval is negligible, to forecast what the flow is likely to be several months or even a year ahead. Further, it is possible to make a similar forecast after the termination of the seasonal rains.

In examining the data relating to the rainfall and the flow of the spring the question which naturally presents itself is whether there has been a falling off during recent years.

Dividing the forty years from 1881 into four periods of ten years, the average annual rainfall for each of these ten-year periods, and the average daily yield of the spring for the last two periods are as follows :—

Period.	Average annual rainfall.	Average daily yield of spring.
1881–1890	15·55 inches	. .
1891–1900	16·13 ,,	. .
1901–1910	13·66 ,,	87,470 gallons.
1911–1920	12·69 ,,	80,240 ,,

The observations of the flow of the spring during the first two periods were not taken so continuously as those during the last two periods, so no attempt has been made to arrive at the average daily yield. However, a

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cursory inspection of the gaugings actually taken will show that the flow was considerably higher during the two earlier periods.

It is perfectly clear from the above figures that there has been a striking diminution both in the rainfall and in the flow of the spring during the last two ten-year periods as compared with the first two ten-year periods.

Taking, however, the ten-year periods from 1902 to 1921 and dividing them into four five-year periods, we get :—

Period.	Average annual rainfall.	Average daily yield of spring.
1902–1906	12·97 inches	68,100 gallons
1907–1911	14·90 ,,	111,280 ,,
1912–1916	11·50 ,,	56,750 ,,
1917–1921	13·73 ,,	109,850 ,,

It appears from these figures that during the twenty years ending 1921 there has been no further diminution either in the rainfall or in the average flow of the spring.

In conclusion, the writer desires to record his thanks to Mr. Charles Stewart, the Chief Meteorologist of the Union, for supplying rainfall data, and to Mr. B. A. Paterson, Town-Clerk of Cradock, for sending the gaugings of the spring.

APPENDIX.

Holtzhuisbaaken Spring.

Rainfall and Spring Gaugings.

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1881		18·56		
1882		14·68		
1883		12·65		
1884	Jan.	2·82		
	Feb.	1·70		
	Mar.	·56		
	Apr.	·25		
	May	1·61		
	June	1·32		

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1884	July	·00		
	Aug.	·20		
	Sept.	·00		
	Oct.	·14	65,000	30th Oct.
	Nov.	·50	64,950	20th Nov.
	Dec.	·00		
		9·10		
1885	Jan.	·34		
	Feb.	1·78		
	Mar.	3·32		
	Apr.	1·44		
	May	1·84		
	June	·00	86,000	6th June
	July	·00		
	Aug.	·47		
	Sept.	1·71		
	Oct.	·80		
	Nov.	1·43		
	Dec.	1·08		
		14·21		
1886		15·63		
1887	Jan.	·30	72,000	31st Jan.
	Feb.	5·41		
	Mar.	2·93		
	Apr.	1·66		
	May	·57		
	June	·00		
	July	2·37		
	Aug.	1·68		
	Sept.	·00		
	Oct.	·24	144,000	5th Oct.
	Nov.	1·82		
	Dec.	·90	129,000	22nd Dec.
		17·88		
1888	Jan.	1·29		
	Feb.	1·98		
	Mar.	1·76	109,400	16th Mar.
	Apr.	2·20		
	May	1·80	110,400	7th May
	June	·20		
	July	·00		
	Aug.	·76		
	Sept.	1·50	102,400	24th Sept.
	Oct.	·65		

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1888	Nov.	·08		
	Dec.	·79		
		13·01		
1889	Jan.	4·98		
	Feb.	1·84		
	Mar.	1·65		
	Apr.	·11	154,000	1st Apr.
	May	·50		
	June	·35	128,304	25th June
	July	·00		
	Aug.	·00	102,720	20th Aug.
	Sept.	·00	91,656	16th Sept.
	Oct.	2·76	81,408	10th Oct.
	Nov.	3·13	90,000	10th Nov.
	Dec.	4·00	143,000	23rd Dec.
		19·32		
1890	Jan.	4·35	193,776	8th Jan.
	Feb.	3·00	252,288	30th Jan.
	Mar.	1·39	294,960	13th Mar.
	Apr.	2·19		
	May	·69	334,080	1st May
	June	·40		
	July	·00		
	Aug.	·00		
	Sept.	·08		
	Oct.	2·22		
	Nov.	3·44		
	Dec.	2·70		
		20·46		
1891				
1892				
1893				
1894				
1895	Jan.	3·00	209,000	Jan.
	Feb.	1·34		
	Mar.	2·22	179,000	Mar.
	Apr.	1·90		
	May	·73	179,000	May
	June	·00		
	July	·22	173,000	July
	Aug.	·18		
	Sept.	·27	128,000	Sept.
	Oct.	·77		
	Nov.	1·66		

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1895 Dec.	2·24		109,000	Dec.
		14·53		
1896 Jan.	1·38		109,000	Jan.
Feb.	1·20			
Mar.	2·22			
Apr.	2·79		143,000	Apr.
May	1·24			
June	·67			
July	·00			
Aug.	·62		179,000	Aug.
Sept.	·00			
Oct.	·00			
Nov.	2·30		139,000	Nov.
Dec.	2·35			
		14·77		
1897		9·78	186,000	Feb.
1898		15·38		
1899		15·08		
1900		14·32		
1901		14·43		
1902		13·34		
1903 Jan.	·35			
Feb.	1·04			
Mar.	·20			
Apr.	1·56			
May	1·12		69,000	19th May
June	·37		69,000	16th June
July	·21			
Aug.	·33			
Sept.	·00			
Oct.	·32			
Nov.	·26		56,000	17th Nov.
Dec.	1·24		50,000	15th Dec.
		7·00		
1904 Jan.	3·25		49,300	19th Jan.
Feb.	3·02		45,560	16th Feb.
Mar.	2·71		55,000	15th Mar.
Apr.	·26		69,000	19th Apr.
May	1·04		70,000	17th May
June	·26		80,000	21st June
July	·06			
Aug.	·27			
Sept.	·25			
Oct.	1·22			

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1904	Nov.	·13		
	Dec.	·33		
		12·80		
1905	Jan.	·93		
	Feb.	2·06		
	Mar.	·63		
	Apr.	1·77		
	May	·75		
	June	·76	45,000	30th June
	July	·00		
	Aug.	·74	51,700	8th Aug.
	Sept.	3·05	51,800	10th Sept.
	Oct.	·90	52,000	13th Oct.
	Nov.	·18	53,000	17th Nov.
	Dec.	1·69	55,700	15th Dec.
		13·46		
1906	Jan.	1·24	62,800	11th Jan.
	Feb.	1·13	66,160	12th Feb.
	Mar.	2·26	66,340	1st Mar.
	Apr.	1·00	70,100	30th Apr.
	May	·74	93,100	29th May
	June	·27		
	July	·00	91,600	30th July
	Aug.	·00		
	Sept.	1·84	95,100	3rd Sept.
	Oct.	2·88		
	Nov.	4·17		
	Dec.	2·73	83,500	4th Dec.
		18·26		
1907		15·76	154,000	16th Jan.
1908	Jan.	·85		
	Feb.	·85		
	Mar.	·80		
	Apr.	·20	80,000	16th Apr.
	May	·95	75,000	19th May
	June	·58		
	July	·33		
	Aug.	·72		
	Sept.	·74	45,000	10th Sept.
	Oct.	·47		
	Nov.	·31		
	Dec.	·86		
		7·46		
1909	Jan.	2·77	45,000	5th Jan.
	Feb.	4·16	57,824	12th Feb.

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1909	Mar.	2·59	83,808	11th Mar.
	Apr.	4·02	83,808	16th Apr.
	May	1·58	139,680	14th May
	June	·00	209,520	11th June
	July	·00	209,520	14th July
	Aug.	·04	169,616	13th Aug.
	Sept.	·50	139,680	21st Sept.
	Oct.	·48	119,725	15th Oct.
	Nov.	·00	104,760	15th Nov.
	Dec.	1·65	89,794	20th Dec.
		17·79		
1910	Jan.	3·20	74,794	14th Jan.
	Feb.	4·45	74,794	13th Feb.
	Mar.	2·08		
	Apr.	·45	119,725	8th Apr.
	May	1·91	139,620	13th May
	June	1·23	139,680	17th June
	July	·48		
	Aug.	·21	136,770	Aug.
	Sept.	·00	136,770	13th Sept.
	Oct.	1·28	136,770	Oct.
	Nov.	·54		
	Dec.	·44	104,760	16th Dec.
		16·27		
1911	Jan.	1·83	93,120	19th Jan.
	Feb.	2·78		
	Mar.	3·58	90,752	2nd Mar.
	Apr.	2·38		
	May	·72	139,680	10th May
	June	·15		
	July	·30		
	Aug.	·62		
	Sept.	·76	104,760	15th Sept.
	Oct.	1·62	104,760	14th Oct.
	Nov.	2·46	104,760	Nov.
	Dec.	·00	83,000	Dec.
		17·20		
1912	Jan.	·80	93,120	16th Jan.
	Feb.	1·22	90,120	16th Feb.
	Mar.	1·11	76,000	15th Mar.
	Apr.	3·29	69,800	13th Apr.
	May	·40	79,840	27th May
	June	·50	79,840	17th June
	July	·57		
	Aug.	·08	64,311	16th Aug.

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1912	Sept.	·00	58,000	13th Sept.
	Oct.	·00	49,660	Oct.
	Nov.	·00	47,000	17th Nov.
	Dec.	·40	45,936	14th Dec.
		8·37		
1913	Jan.	1·63	42,000	17th Jan.
	Feb.	3·38	40,904	14th Feb.
	Mar.	2·18	40,904	14th Mar.
	April	·41	40,000	15th Apr.
	May	·11	50,000	16th May
	June	1·29		
	July	·00	62,000	11th July
	Aug.	·09		
	Sept.	3·23		
	Oct.	1·53	59,946	17th Oct.
	Nov.	1·11	59,946	18th Nov.
	Dec.	·00		
		14·96		
1914	Jan.	·56	64,800	20th Jan.
	Feb.	2·59	62,856	12th Feb.
	Mar.	2·46	69,840	13th Mar.
	Apr.	·91	69,840	19th Apr.
	May	2·61	73,948	6th May
	June	·53		
	July	·00	83,808	2nd July
	Aug.	·39	83,808	12th Aug.
	Sept.	·00	69,840	29th Sept.
	Oct.	·67	62,856	18th Oct.
	Nov.	2·64	55,872	15th Nov.
	Dec.	·69	50,052	13th Dec.
		14·05		
1915	Jan.	2·50	49,389	17th Jan.
	Feb.	1·30	56,900	20th Feb.
	Mar.	·00	64,300	10th Mar.
	Apr.	1·12	72,876	19th Apr.
	May	1·72	69,840	18th May
	June	·54	62,856	11th June
	July	·00	52,380	18th July
	Aug.	·05	46,600	10th Aug.
	Sept.	·21	39,162	15th Sept.
	Oct.	·40	36,974	12th Oct.
	Nov.	·17	33,523	14th Nov.
	Dec.	1·47	33,082	19th Dec.
		9·48		
1916	Jan.	·62	34,920	7th Jan.

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1916	Feb.	·74	38,680	10th Feb.
	Mar.	2·71	44,897	20th Mar.
	Apr.	·86	43,693	2nd Apr.
	May	1·62	48,306	10th May
	June	·00	52,380	14th June
	July	·15	46,901	18th July
	Aug.	·00	34,920	14th Aug.
	Sept.	·45	33,301	11th Sept.
	Oct.	2·09	29,337	15th Oct.
	Nov.	·18	46,560	11th Nov.
	Dec.	1·25	29,337	11th Dec.
		10·67		
1917	Jan.	1·46	33,976	14th Jan.
	Feb.	3·98	25,792	14th Feb.
	Mar.	4·83	55,872	14th Mar.
	Apr.	1·34	109,314	11th Apr.
	May	·38	81,104	8th May
	June	1·09	59,020	17th June
	July	·45	47,439	11th July
	Aug.	·59	44,897	15th Aug.
	Sept.	1·10	41,588	12th Sept.
	Oct.	1·60	69,437	14th Oct.
	Nov.	1·78	55,000	18th Nov.
	Dec.	·96	46,820	12th Dec.
		19·56		
1918	Jan.	3·57	67,769	9th Jan.
	Feb.	1·28	88,219	25th Feb.
	Mar.	4·35	111,289	9th Mar.
	Apr.	·70	193,403	21st Apr.
	May	·86	239,451	19th May
	June	·22	232,800	16th June
	July	·04	209,520	10th July
	Aug.	·80	168,472	18th Aug.
	Sept.	1·67	146,176	15th Sept.
	Oct.	1·48	130,000	9th Oct.
	Nov.	·00	132,328	13th Nov.
	Dec.	1·13	132,328	16th Dec.
		16·10		
1919	Jan.	·00	104,760	19th Jan.
	Feb.	·47	85,225	16th Feb.
	Mar.	·59	83,220	16th Mar.
	Apr.	2·14	83,220	15th Apr.
	May	·10	68,000	May
	June	·03	68,833	14th June
	July	·00	64,467	11th July

Rainfall in inches.			Flow of spring in gallons per 24 hours.	Date of gauging.
1919	Aug.	·03	57,586	17th Aug.
	Sept.	·00	52,671	14th Sept.
	Oct.	·08	43,200	20th Oct.
	Nov.	·56	40,953	16th Nov.
	Dec.	·11	39,000	14th Dec.
		4·11		
1920	Jan.	1·50	41,332	18th Jan.
	Feb.	4·41	55,872	15th Feb.
	Mar.	2·65	119,725	30th Mar.
	Apr.	1·09	119,725	Apr.
	May	·19	152,379	12th May
	June	·08	193,224	9th June
	July	·14	173,396	11th July
	Aug.	·00	163,226	9th Aug.
	Sept.	·35	143,670	19th Sept.
	Oct.	·53	135,174	17th Oct.
	Nov.	·31		
	Dec.	1·12	119,725	3rd Dec.
		12·37		
1921	Jan.	·76	120,000	12th Jan.
	Feb.	2·86		
	Mar.	2·95	135,897	22nd Mar.
	Apr.	2·85	157,145	17th Apr.
	May	1·71	163,251	13th May
	June	·20	186,240	23rd June
	July	·00	161,369	10th July
	Aug.	·11	147,828	17th Aug.
	Sept.	·00	139,680	23rd Sept.
	Oct.	·70	111,744	3rd Oct.
	Nov.	3·02		
	Dec.	1·36	130,950	12th Dec.
		16·52		
1922	Jan.	2·27		
	Feb.	·39	145,421	1st Feb.
	Mar.	·66	122,645	9th Mar.
	Apr.	·71		
	May	·09	104,760	9th May
	June	·65	104,760	9th June
	July	·48		
	Aug.	·20	86,598	13th Aug.
	Sept.	·64	81,746	11th Sept.
	Oct.	·00	76,429	2nd Oct.
	Nov.	2·67	66,154	8th Nov.
	Dec.	1·02	61,774	17th Dec.
		9·78		

NOTE ON ZEIPEL'S CONDENSATION-THEOREM AND RELATED RESULTS.

By Sir Thomas Muir, F.R.S.

1. Both Zeipel's papers on determinants * are now over fifty years old, and, though they have not been entirely neglected, it cannot be said that they have received sufficient and sufficiently discriminating attention. The text-books of determinants—which of course ought to keep a watchful eye on any attractive facet of their subject—have in particular been strangely remiss. All the smaller and most of the larger of them quite ignore both papers. In only three, indeed, is the special subject referred to, Pascal giving the evaluation of one determinant, Günther the same and one transformation, and Scott the chief of the generalised but less attractive theorems of the second paper.

In view of this it seems worth while to draw attention to one or two of the basic results of the first paper, and to a number of deductions that cluster somewhat picturesquely round them.

2. What may be viewed as Zeipel's fundamental determinant is

$$
\begin{vmatrix}
m_p & m_{p+1} & \cdots & m_{p+r} \\
(m+1)_p & (m+1)_{p+1} & \cdots & (m+1)_{p+r} \\
\cdots & \cdots & \cdots & \cdots \\
(m+r)_p & (m+r)_{p+1} & \cdots & (m+r)_{p+r}
\end{vmatrix}, \text{ or A say,}
$$

where h_k or $(h)_k$ stands for the combinatory number $h(h-1)\ldots(h-k+1)/k!$, h then being spoken of as the *base* and k as the *suffix* of the said number. He arrives at four results in regard to it, the first being a non-determinant form for it, namely, the p-factored expression

$$
\frac{(m+r)_{r+1}}{(p+r)_{r+1}} \cdot \frac{(m+r-1)_{r+1}}{(p+r-1)_{r+1}} \cdot \ldots \cdot \frac{(m+r-p+1)_{r+1}}{(r+1)_{r+1}}.
$$

* Om determinanter, hvars elementer äro binomialkoefficienter. *Lunds' Univ. Årsskrift*, II. (1865), 68 pp. Om determinanter, hvilkas elementar äro binomialkoefficienter multiplicerade med vissa faktorer. *Lunds' Univ. Årsskrift*, VIII. (1871), 36 pp.

His next is the transformation of it into

$$\begin{vmatrix} m_{p-r} & m_{p-r+1} & \cdots\cdots & m_p \\ m_{p-r+1} & m_{p-r+2} & \cdots\cdots & m_{p+1} \\ \cdot & \cdot & \cdots\cdots\cdots & \cdot \\ m_p & m_{p+1} & \cdots\cdots & m_{p+r} \end{vmatrix}, \text{ or B say,}$$

where now the base of every element is the same, and the suffixes are the integers from $p-r$ to $p+r$ arranged in persymmetric fashion; in other words, the new form is the persymmetric determinant

$$\mathrm{P}(m_{p-r},\ m_{p-r+1},\quad \cdots\cdots\ ,\ m_{p+r}).$$

This is followed by another transformation of A, namely, into

$$\begin{vmatrix} m_p & (m+1)_{p+1} & \cdots\cdots & (m+r)_{p+r} \\ (m+1)_p & (m+2)_{p+1} & \cdots\cdots & (m+r+1)_{p+r} \\ \cdot & \cdot & \cdots\cdots\cdots & \cdot \\ (m+r)_p & (m+r+1)_{p+1} & \cdots\cdots & (m+2r)_{p+r} \end{vmatrix}, \text{ or D say,}$$

where the suffixes are as in the original determinant, and the bases form a persymmetric array from m to $m+2r$. Lastly, there is his fourth variant for A, namely,

$$\begin{vmatrix} (m+r-p+1)_{r+1} & (m+r-p+1)_{r+2} & \cdots\cdots & (m+r-p+1)_{r+p} \\ (m+r-p+2)_{r+1} & (m+r-p+2)_{r+2} & \cdots\cdots & (m+r-p+2)_{r+p} \\ \cdot & \cdot & \cdots\cdots\cdots & \cdot \\ (m+r)_{r+1} & (m+r)_{r+2} & \cdots\cdots & (m+r)_{r+p} \end{vmatrix}, \text{ or } \alpha \text{ say,}$$

which is exactly of the same form as the original, the bases being alike throughout each row, and the suffixes alike throughout each column. The noteworthy point, however, now is that the order of the determinant is no longer unaltered, being the pth instead of the $(r+1)^{\text{th}}$. And as p is necessarily less than m, while r may be as great an integer as we please, this means that the new order is in general lower than the old, and that, so to say, the original determinant has been condensed. Almost equally noteworthy is the fact that the new form is not got this time from the original by transformation: the equivalence of the two is inferred merely from their being " things that are equal to the same thing." Since Zeipel's discovery of it, it has apparently been entirely lost sight of, though in some respects by far the most interesting of the four equalities.

3. These results of 1865 having now been made clear, let us try to add to their interest by proceeding to make some fresh developments.

In the first place, the three forms A, B, D do not stand alone : there are three others of equal importance. One of them is

$$\begin{vmatrix} m_{p-r} & (m+1)_{p-r+1} & \cdots & (m+r)_p \\ (m+1)_{p-r+1} & (m+2)_{p-r+2} & \cdots & (m+r+1)_{p+1} \\ \cdot & \cdot & \cdot & \cdot \\ (m+r)_p & (m+r+1)_{p+1} & \cdots & (m+2r)_{p+r} \end{vmatrix} , \text{ or C say,}$$

where the bases form a persymmetric array, namely, the persymmetric array of D, and the suffixes form a persymmetric array, namely, the persymmetric array of B. C is thus in a sense doubly persymmetric, being

$$P\big(m_{p-r}, (m+1)_{p-r+1}, \quad \cdots \quad , (m+2r)_{p+r}\big).$$

Another form is

$$\begin{vmatrix} m_{p+r} & (m+1)_{p+r} & \cdots & (m+r)_{p+r} \\ (m+1)_{p+r} & (m+2)_{p+r} & \cdots & (m+r+1)_{p+r} \\ \cdot & \cdot & \cdot & \cdot \\ (m+r)_{p+r} & (m+r+1)_{p+r} & \cdots & (m+2r)_{p+r} \end{vmatrix} , \text{ or E say,}$$

where again the bases form the persymmetric array extending from m to $m+2r$, and the suffixes are, like the bases in B, constant throughout : in other words, what we have got is

$$P\big(m_{p+r}, (m+1)_{p+r}, \quad \cdots \quad , (m+2r)_{p+r}\big).$$

Lastly, there is the form

$$\begin{vmatrix} (m)_{p-r} & (m)_{p-r+1} & \cdots & (m)_p \\ (m+1)_{p-r+1} & (m+1)_{p-r+2} & \cdots & (m+1)_{p+1} \\ \cdot & \cdot & \cdot & \cdot \\ (m+r)_p & (m+r)_{p+1} & \cdots & (m+r)_{p+r} \end{vmatrix} , \text{ or F say,}$$

where the bases are alike throughout each row, are, in fact, the same as in A, and the suffixes are as in B the integers from $p-r$ to $p+r$ arranged in persymmetric fashion.

4. These three additional transformations can be brought about in a manner exactly similar to that employed by Zeipel in the case of the others. It will be more instructive, however, if we condense the operations, making multiplication the agent in every case. The facts can then be succinctly put as follows :—

$$\begin{vmatrix} \cdots & -1 & 1 & -1 & 1 \\ \cdots & 3 & -2 & 1 & \cdot \\ \cdots & -3 & 1 & \cdot & \cdot \\ \cdots & 1 & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \end{vmatrix} \times_c A = B,$$

$$A \times_r \begin{vmatrix} 1 & \cdot & \cdot & & \cdot & \cdot \cdot \cdot \cdot \\ 1 & 1 & \cdot & & \cdot & \cdot \cdot \cdot \cdot \\ 1 & 2 & 1 & & \cdot & \cdot \cdot \cdot \cdot \\ 1 & 3 & 3 & 1 & & \cdot \cdot \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \cdot \cdot \end{vmatrix} = D,$$

$$\begin{vmatrix} \cdot \cdot \cdot \cdot & \cdot & \cdot & 1 \\ \cdot \cdot \cdot \cdot & \cdot & 1 & 1 \\ \cdot \cdot \cdot \cdot & 1 & 2 & 1 \\ \cdot \cdot \cdot 1 & 3 & 3 & 1 \end{vmatrix} \times_r A = E,$$

$$\begin{vmatrix} \cdot \cdot \cdot \cdot & 1 & 1 & 1 & 1 \\ \cdot \cdot \cdot \cdot & 3 & 2 & 1 & \cdot \\ \cdot \cdot \cdot \cdot & 3 & 1 & \cdot & \cdot \\ \cdot \cdot \cdot \cdot & 1 & \cdot & \cdot & \cdot \end{vmatrix} \times_c B = F,$$

$$F \times_r \begin{vmatrix} 1 & \cdot & \cdot & & \cdot & \cdot \cdot \cdot \cdot \\ 1 & 1 & \cdot & & \cdot & \cdot \cdot \cdot \cdot \\ 1 & 2 & 1 & & \cdot & \cdot \cdot \cdot \cdot \\ 1 & 3 & 3 & 1 & & \cdot \cdot \cdot \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \cdot \cdot \end{vmatrix} = C.$$

As an example let us take the case where $m=8$, $r=3$, $p=3$. The six equivalent forms A, B, C, D, E, F then are

$$\begin{vmatrix} 8_3 & 8_4 & 8_5 & 8_6 \\ 9_3 & 9_4 & 9_5 & 9_6 \\ 10_3 & 10_4 & 10_5 & 10_6 \\ 11_3 & 11_4 & 11_5 & 11_6 \end{vmatrix}, \quad \begin{vmatrix} 8_0 & 8_1 & 8_2 & 8_3 \\ 8_1 & 8_2 & 8_3 & 8_4 \\ 8_2 & 8_3 & 8_4 & 8_5 \\ 8_3 & 8_4 & 8_5 & 8_6 \end{vmatrix}, \quad \begin{vmatrix} 8_0 & 9_1 & 10_2 & 11_3 \\ 9_1 & 10_2 & 11_3 & 12_4 \\ 10_2 & 11_3 & 12_4 & 13_5 \\ 11_3 & 12_4 & 13_5 & 14_6 \end{vmatrix},$$

$$\begin{vmatrix} 8_3 & 9_4 & 10_5 & 11_6 \\ 9_3 & 10_4 & 11_5 & 12_6 \\ 10_3 & 11_4 & 12_5 & 13_6 \\ 11_3 & 12_4 & 13_5 & 14_6 \end{vmatrix}, \quad \begin{vmatrix} 8_6 & 9_6 & 10_6 & 11_6 \\ 9_6 & 10_6 & 11_6 & 12_6 \\ 10_6 & 11_6 & 12_6 & 13_6 \\ 11_6 & 12_6 & 13_6 & 14_6 \end{vmatrix}, \quad \begin{vmatrix} 8_0 & 8_1 & 8_2 & 8_3 \\ 9_1 & 9_2 & 9_3 & 9_4 \\ 10_2 & 10_3 & 10_4 & 10_5 \\ 11_3 & 11_4 & 11_5 & 11_6 \end{vmatrix}.$$

5. Our next point is that since α is exactly of the same form as A, there must be five derived equivalent forms $\beta, \gamma, \delta, \epsilon, \phi$ of the pth order corresponding to B, C, D, E, F. Further, noting that in A the first base, the first suffix, and the order of the determinant are

$$m \qquad p \qquad r+1$$

and that in α the corresponding numbers are

$$m+r-p+1 \qquad r+1 \qquad p,$$

we readily see that

$$\beta \equiv P\big((m+r-p+1)_{r-p+2}, (m+r-p+1)_{r-p+3}, \ldots, (m+r-p+1)_{r+p}\big)$$

$$\gamma \equiv P\big((m+r-p+1)_{r-p+2}, (m+r-p+2)_{r-p+3}, \ldots, (m+r+p-1)_{r+p}\big)$$

$$\delta \equiv \begin{vmatrix} (m+r-p+1)_{r+1} & (m+r-p+2)_{r+2} & \cdots & (m+r)_{r+p} \\ (m+r-p+2)_{r+1} & (m+r-p+3)_{r+2} & \cdots & (m+r+1)_{r+p} \\ \cdot & \cdot & \cdot & \cdot \\ (m+r)_{r+1} & (m+r+1)_{r+2} & \cdots & (m+r+p-1)_{r+p} \end{vmatrix}$$

$$\epsilon \equiv P\big((m+r-p+1)_{p+r}, (m+r-p+2)_{p+r}, \ldots, (m+r+p-1)_{p+r}\big)$$

$$\phi \equiv \begin{vmatrix} (m+r-p+1)_{r-p+2} & (m+r-p+1)_{r-p+3} & \cdots & (m+r-p+1)_{r+1} \\ (m+r-p+2)_{r-p+3} & (m+r-p+2)_{r-p+4} & \cdots & (m+r-p+2)_{r+2} \\ \cdot & \cdot & \cdot & \cdot \\ (m+r)_{r+1} & (m+r)_{r+2} & \cdots & (m+r)_{r+p} \end{vmatrix}$$

and that therefore, putting $m=8$, $p=3$, $r=3$, we obtain as equivalents of each of the 4-line determinants of § 4 the six 3-line determinants

$$\begin{vmatrix} 9_4 & 9_5 & 9_6 \\ 10_4 & 10_5 & 10_6 \\ 11_4 & 11_5 & 11_6 \end{vmatrix}, \quad \begin{vmatrix} 9_2 & 9_3 & 9_4 \\ 9_3 & 9_4 & 9_5 \\ 9_4 & 9_5 & 9_6 \end{vmatrix}. \quad \begin{vmatrix} 9_2 & 10_3 & 11_4 \\ 10_3 & 11_4 & 12_5 \\ 11_4 & 12_5 & 13_6 \end{vmatrix},$$

$$\begin{vmatrix} 9_4 & 10_5 & 11_6 \\ 10_4 & 11_5 & 12_6 \\ 11_4 & 12_5 & 13_6 \end{vmatrix}, \quad \begin{vmatrix} 9_6 & 10_6 & 11_6 \\ 10_6 & 11_6 & 12_6 \\ 11_6 & 12_6 & 13_6 \end{vmatrix}, \quad \begin{vmatrix} 9_2 & 9_3 & 9_4 \\ 10_3 & 10_4 & 10_5 \\ 11_4 & 11_5 & 11_6 \end{vmatrix}.$$

We thus have in all *twelve* determinants having a common value, the said value in the special case considered being

$$\frac{11_4}{6_4} \cdot \frac{10_4}{5_4} \cdot \frac{9_4}{4_4} \quad i.e. \quad 116424.$$

6. But not only is the set of p-line determinants related as indicated to the $(r+1)$-line set, each of them, save two, is a minor of the corresponding member of the other set, and when $r=p$ is a *primary* minor. For example, in the case where $m, p, r=8, 3, 3$, α which equals A is the last primary minor of A, and

$$\text{D,} \quad i.e. \quad \begin{vmatrix} 8_3 & 9_4 & 10_5 & 11_6 \\ 9_3 & 10_4 & 11_5 & 12_6 \\ 10_3 & 11_4 & 12_5 & 13_6 \\ 11_3 & 12_4 & 13_5 & 14_6 \end{vmatrix} = \text{co-factor of } 11_3 \text{ in D itself.}$$

7. Zeipel's theorem

$$A = a,$$

to which we have sought to draw attention in our title above, is thus seen to be expressible in an interesting variety of ways. Indeed, if viewed as a condensation-theorem—that is to say, a theorem giving the reduction of one determinant to another of lower order—the equating of any one of the set A, B, . . ., F to any one of the set a, β, . . ., ϕ constitutes a statement of the theorem. It is a special attraction of each of the particular six

$$A = a,$$
$$B = \beta,$$
. . . . . .

that the two determinants involved are exactly alike in form.

8. It is important to note, however, that the theorem $A = a$ is not a true " reduction " theorem : in other words, having got a of a lower order than A we cannot by repetition obtain a determinant of lower order than a. Indeed, if, with a view to finding such a condensation of a, we proceed to form its first base, its first suffix and its order as those of a were formed from those of A, we find ourselves simply led back to $m, p, r+1$: for example, the first base is

$$(m - p + r + 1) - (r + 1) + p, \quad \text{i.e.} \quad m.$$

On this as on other points light would doubtless be thrown by arriving at a process for the actual transformation of any one of A, B, . . . into any one of a, β, . . .

9. Of course if our twelve equivalent determinants were taken and every element changed by using the equality $h_k = h_{h-k}$, we should obtain other twelve determinants equivalent in substance but unimportant as being only superficially different in form. In regard to them it need only be noted that the operation in question does not always produce a determinant of the same form as that operated on, but that nevertheless when performed on a complete set of six a similar complete set is obtained. Thus, if we call the two new complete sets A', B', . . . , F', a', β', . . . , ϕ', it is found that C gives rise to E' and E to C', A to F' and F to A'.

The existence of these 3rd and 4th sets may be differently intimated by saying that *every determinant of the 1st set remains unaltered on increasing all its bases by* $m - 2p$, *and every determinant of the 2nd set by increasing all its bases by* $m - r - p - 1$.

TWO NEW SPECIES OF NEMATODES FROM THE ZEBRA.

By Gertrud Theiler, B.A., Ph.D.

(With Plate I.)

The material forming the subject of the present paper was found in a large collection of equine nematodes, made at the Onderstepoort Veterinary Research Laboratory in 1916, and studied in the Zoological Laboratory of the University of Neuchâtel.

The zebras from which these specimens were taken had been shot at Bossieshoek, Rustenburg district. Besides these two new species, the zebras harboured several other species of nematodes, a description of which is soon to be published, together with that of the intestinal nematodes of other equines.

NEMATODA.

Superfamily STRONGYLOIDEA Weinland, 1858.

Family STRONGYLIDAE Baird, 1853.

Subfamily Strongylinae Railliet, 1893.

Tribe Cylicostomeae Railliet et Henry, 1912.

Genus *Cylindropharynx* Leiper, 1911.

Diagnosis.—Buccal capsule abnormally deep. External leaf crown consists of six large teeth, corresponding in position to the head papillae. The two situated laterally are larger than four submedians, each is notched, longitudinally grooved, suggesting an origin by fusion of at least two elements. Dorsally and ventrally the external leaf crown is deficient, but from each of the dorsal and ventral lips of the mouth collar there projects horizontally inward a broad crescentric plate, the free concave margin of which is directed towards the axis of the mouth. Internal leaf crown consists of twelve large elements. Margin of bursa denticulate. Posterior extremity of female straight and pointed.

Type-species *C. brevicauda* Leiper, 1911.

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Cylindropharynx intermedia n. sp.

Size.—The males measure 8·5–10 mm. in length, with a maximum breadth of 420–480 μ.

The females measure 10–11 mm. in length, with a maximum breadth of 520 μ. Cuticle shows transverse annulation except in the cephalic region.

Head.—140–160 μ in breadth; head and neck narrower than the rest of the body; increase in breadth about midway down the œsophagus.

Mouth collar appears almost circular in a lateral view.

Head papillae.—Submedian papillae are conspicuous; each consists of a leaf-shaped appendage carried on a cylindrical base. Laterals are not prominent; they are situated in a slight depression of the oral margin and have trifurcated extremities.

Mouth capsule has a depth of 440–460 μ in the male, 500–520 μ in the female, with a maximum breadth at its anterior extremity of 85–96 μ in the male and 120 μ in the female. Walls stout, not straight, tapering slightly at both extremities.

Dorsal gutter does not project into the mouth capsule.

Leaf crowns are as in the type species, *i.e.* the externals consist of six large elements corresponding in position to the head papillae. The two situated laterally are larger than the four submedians; each is notched and longitudinally grooved, suggesting an origin by fusion of at least two elements. Dorsally and ventrally the external leaf crown is deficient, but from each of the dorsal and ventral lips of the mouth collar there projects horizontally inwards a broad crescentic plate, the free concave margin of which is directed towards the axis of the mouth. The internal leaf crown consists of twelve broad, elongated leaves arising from the anterior margin of the mouth capsule; the leaves are extremely thick, in profile they might be taken for anteriorly directed branches of the oral capsule.

Oesophagus, short and roughly cylindrical in shape, shows a slight decrease in width at the level of the nerve ring, immediately behind its union with the buccal capsule. It is 470–540 μ in length in the male and 600–640 μ in the female, with a maximum breadth of 160 μ in the male and 200 μ in the female.

Excretory pore and cervical papillae at about the same level behind the nerve ring, 560–640 μ in the male, and 620–660 μ in the female, from the anterior extremity. The left papilla is a little in front of the right.

Posterior extremity, male.—The bursa has a short dorsal lobe (280–300 μ in length), whose outline may be rounded or bluntly triangular. The lateral lobes do not embrace the genital cone. The external branch of the dorsal ray is deeply bifurcated into two finger-like processes, the external

of which is the longer. The externo-dorsal ray shows a groove down its centre, suggesting a fusion of two rays. Genital cone of remarkable size, measuring 240–280 μ in length, with an average breadth of 160 μ. It is retractile. Dermal collar well developed, more especially ventrally. Genital appendages as in the type-species, *i.e.* a pair of finger-shaped appendages with rounded ends occur just behind the genital opening, whilst an irregular number of delicate processes are scattered over the dorsal surface of the cone. Spicules 920 μ.

Posterior extremity, female.—At the vulva, situated 1·5–1·6 mm. from tip of tail, the body has a diameter of 360 μ; behind this level the body tapers to a pointed tail. Anus 260–320 μ from the posterior end.

Occurrence.—Present in the pelvic flexure and dorsal colon, where it is the commonest parasite of the three zebra examined.

Discussion.—This worm most closely resembles *C. brevicauda*, from which, however, it may be distinguished by its greater size and by the posterior extremity of the female. It is easily distinguished from *C. longicauda* and *C. rhodesiensis* by the nature of its genital cone.

Superfamily FILARIOIDEA Weinland, 1858.

Family SPIRURIDAE Oerley, 1885.

Subfamily SPIRURINAE Railliet, 1915.

Genus *Habronema*, Diesing, 1861.

Diagnosis.—Body provided with lateral alae. The cervical papillae are situated in front of the level of the nerve ring. The mouth is surrounded by four lips : two laterals which may be trilobed, and a dorsal and a ventral. Vulva small and situated before the middle of the body. The ovijector has a piriform vestibule which is connected to an S-shaped sphincter. Uteri divergent ; eggs with thick shells ; ovoviviparous. The caudal alae of the male are large, curved ventrad ; four pairs of preanal papillae, postanal papillae asymmetrical ; two unequal spicules and a gubernaculum.

Type-species *H. muscae* Carter, 1861.

Habronema zebrae n. sp.

Size and shape.—Intermediate in size between the South African forms of *H. microstoma* and *H. muscae*. The males being 10–13 mm. in length, with a maximum breadth of 220–240 μ. The females measure 17–18 mm. in length, with a maximum breadth of 340 μ; the worms are filiform, tapering at both ends, reaching their maximum breadth just behind the oesophagus, and retaining it throughout practically their whole length.

Cuticle very much as in *H. microstoma*.

Head.—The general plan of the head, mouth parts, pharynx, and oeso-

phagus is the same as for *H. microstoma.*   It differs from the latter, however, in its exceptionally deep pharynx, which recalls that of the genus *Cylindropharynx.*   This measures 140–160 μ in depth, and has a diameter of 22–24 μ. Walls are not thick, and diverge slightly anteriorly.

Cervical papillae are situated in front of the nerve ring, 280 μ from anterior extremity, and the *excretory pore* opens immediately behind this level.

Entire oesophagus long, up to 3·3 mm. in length in females.

Posterior extremity, male, is usually coiled spirally.   Bursal wings present, showing the usual longitudinal scale-like ridges or cuticular bosses.   The genital papillae are stalked.   There are four pairs of preanal papillae, the left series slightly in front of the right ; and one large unpaired median-papilla situated on the upper lip of the cloaca.   The four postanal papillae are asymmetrically arranged.   On the right side the two papillae are situated at a level about half-way between the anus and the posterior extremity.   On the left the one papilla is situated at a level immediately behind the anus, whilst the other is not far removed from the tip of the tail. Rarely a third papilla may be present on the right side, in which case it is situated opposite the left posterior papilla.   Tip of tail is provided with several smaller papillae.

Spicules.—Two unequal, the left very long and slender, 1·7–1·9 mm. in length ; the right short and thick, 400–560 μ in length.

A small irregularly shaped gubernaculum is present.

Posterior extremity, female.—Vulva slightly in front of anterior third of body.   The ovijector resembles that of *H. muscae.*   The vulva may be displaced out of its mid-ventral position, not as much as in the type-species, however.   From the vulva it passes for a short distance around the body beneath the cuticle, and then enters the body-cavity, where it is surrounded by a muscular layer (this corresponds to the vestibule of Seurat), 480–560 μ. As in *H. muscae,* a gland is placed at the base of the vestibule, between the muscular tunic and the cuticle   The sphincter is S-shaped, " la trompe " of Seurat, measuring 720–760 μ, branches into the two uteri, which run backwards, and run parallel for a longer distance than in *H. muscae.*   The ovaries wind round the uteri.   Seminal vesicle present.   Tail bluntly pointed, and usually curves dorsally, with a caudal gland opening at its extremity.

Discussion.—In general, *H. zebrae* most closely resembles *H. muscae* as regards the female genital organs and male spicules, and resembles *H. microstoma* by the presence of the dorsal and ventral processes in the pharynx. It differs from both in its size, deeper pharynx, and in the arrangement of the postanal papillae.

Occurrence.—Present in fairly large numbers in the stomach of the zebra.
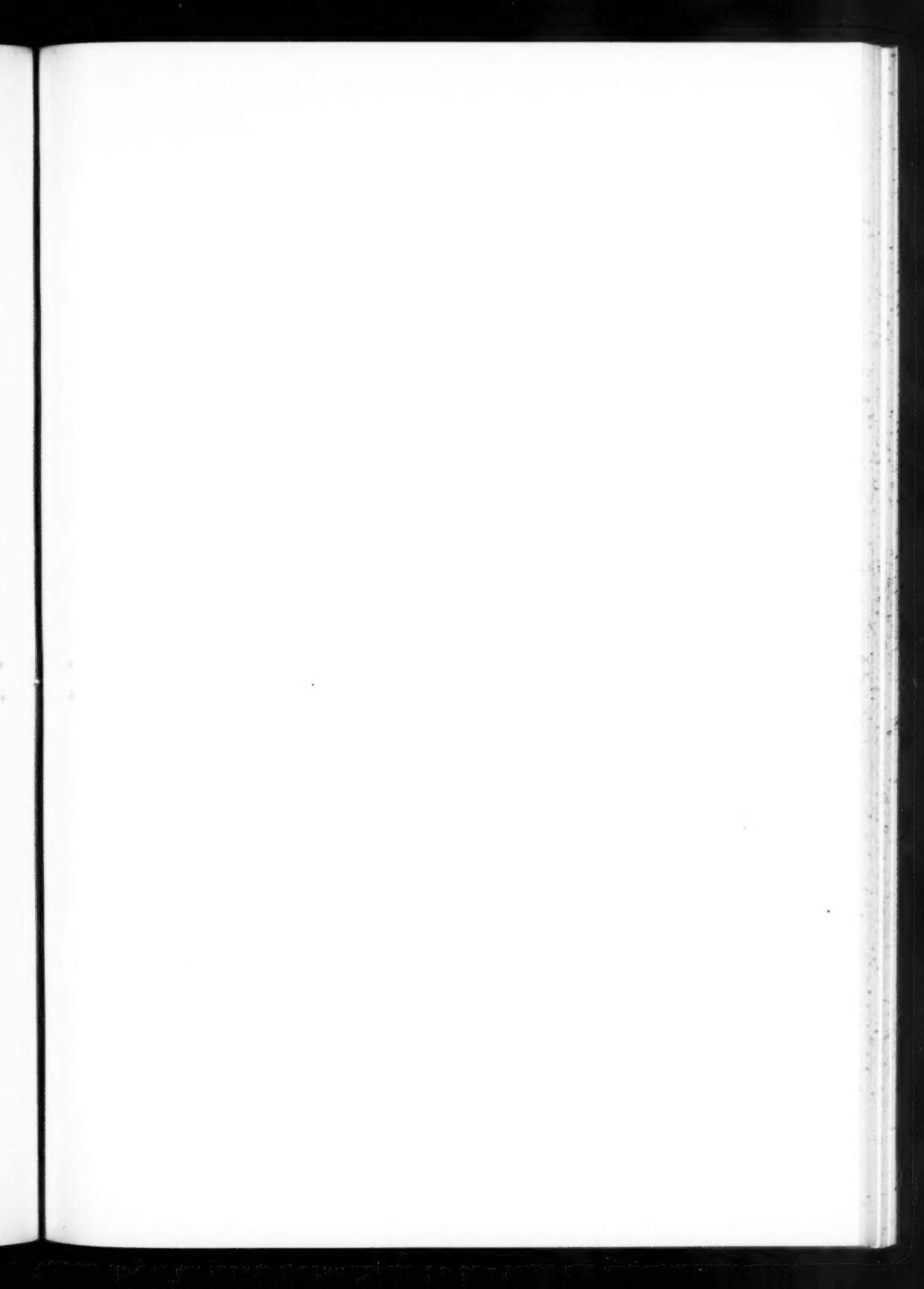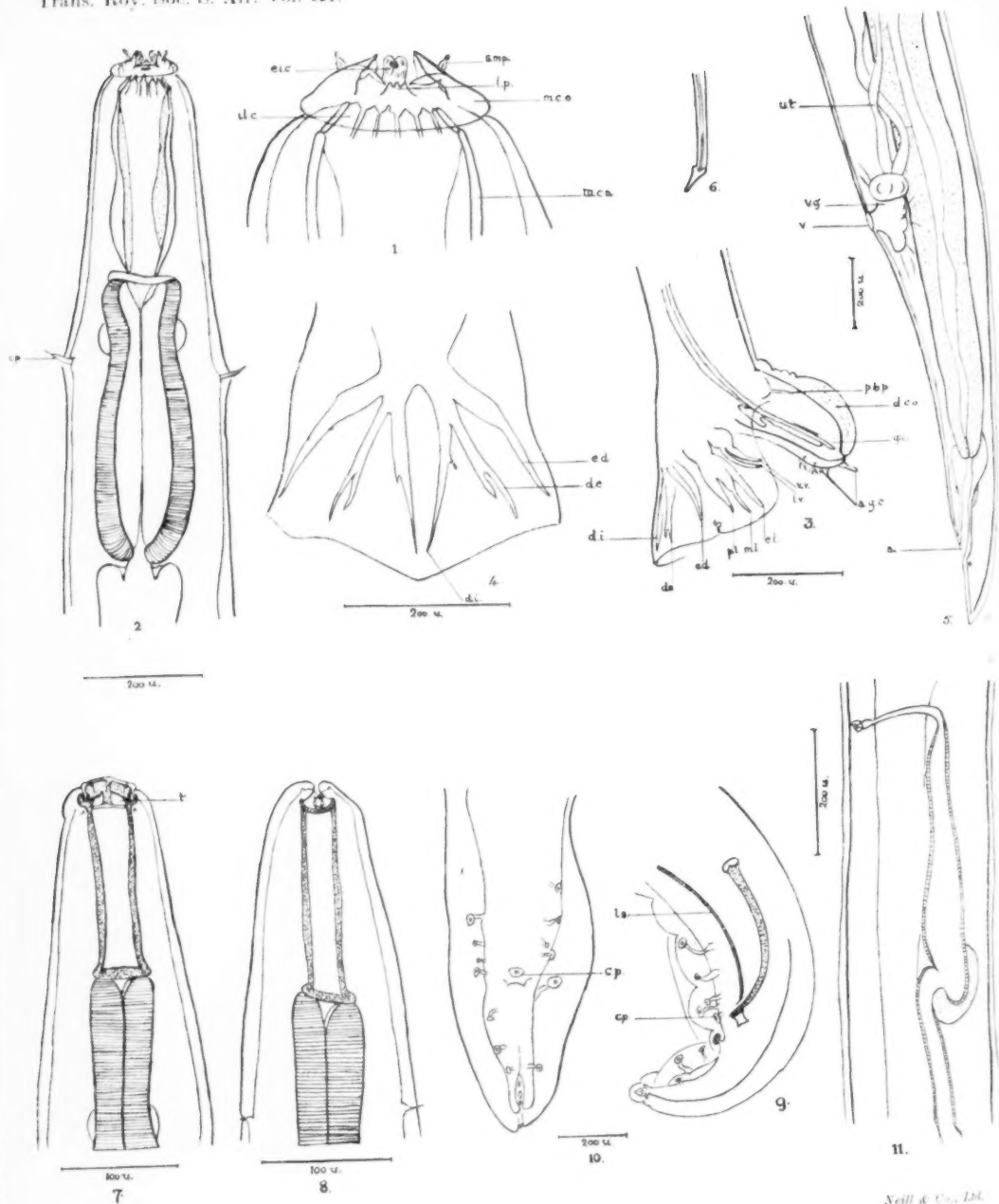
Plate I.

EXPLANATION OF PLATE.

Cylindropharynx intermedia n. sp.

Fig. 1. Anterior extremity, lateral view. *e.l.c.*, external leaf crown; *i.l.c.*, internal leaf crown; *l.p.*, lateral papilla; *m.co.*, mouth collar; *m.ca.*, wall of mouth capsule; *sm.p.*—submedian papilla.

Fig. 2. Anterior body region, dorsal view. *c.p.*, cervical papilla.

Fig. 3. Posterior extremity of male, lateral view. *g.c.*, genital cone; *d.co.*, dermal collar; *pb.p.*, prebursal papillae; *a.g.c.*, appendages of genital cone; *v.v.*, ventro-ventral ray; *l.v.*, latero-ventral ray; *e.l.*, *m.l.*, and *p.l.*, externo-, medio-, and postero-lateral rays resp.; *e.d.*, externo-dorsal ray; *d.e.*, external branch of dorsal ray; *d.i.*, internal branch of same.

Fig. 4. Posterior extremity of male, dorsal view.

Fig. 5. Posterior extremity of female, lateral view. *ut.*, uterus; *vg.*, vagina; *v.*, vulva; *a.*, anus.

Fig. 6. Distal extremity of spicule.

Habronema zebrae n. sp.

Fig. 7. Anterior extremity, lateral view. *t.*, pharyngeal tooth or tridentate process.

Fig. 8. Anterior extremity, dorsal view.

Fig. 9. Posterior extremity of male, lateral view, showing preanal papillae of left side only, and postanal papillae of right and left side. *l.s.*, left spicule; *c.p.*, unpaired papilla situated on upper lip of cloaca.

Fig. 10. Posterior extremity of male, ventral view.

Fig. 11. Region of vulva of female.

NOTE ON THE SUCCESSIVE DIFFERENTIATION OF A PRODUCT OF LINEAR FUNCTIONS.

By Sir Thomas Muir, F.R.S.

1. So far as one can gather from the usual sources, no explicit and uniform mode has been discovered for expressing the results of differentiating the product of a series of linear functions of a constant set of variables. By reason of the fact that all the results consist of positive terms, efforts have naturally been made to utilise a multiple-sigma notation, but the outcome would not be wrongly spoken of as a cumbersome failure. Recently a chance observation made while dealing with the *second* differential-co-efficients suggested to me a general trial of the notation of permanents —Cauchy's counterpart to determinants : and fortunately this was attended with complete success.

2. Let us take the case where there are four functions

$$a_1 x + b_1 y + c_1 z + d_1 w,$$
$$a_2 x + b_2 y + c_2 z + d_2 w,$$
$$a_3 x + b_3 y + c_3 z + d_3 w,$$
$$a_4 x + b_4 y + c_4 z + d_4 w,$$

and let us denote them by u_1, u_2, u_3, u_4 respectively and their product by U. Further, let us write U for differentiation purposes in the futile-looking form

$$\frac{1}{4!} \overset{+}{\begin{vmatrix} u_1 & u_1 & u_1 & \overset{+}{u_1} \\ u_2 & u_2 & u_2 & u_2 \\ u_3 & u_3 & u_3 & u_3 \\ u_4 & u_4 & u_4 & u_4 \end{vmatrix}}.$$

Then recalling that the differentiation of a permanent is effected by exactly the same procedure as the differentiation of a determinant, namely, by taking the sum of the permanents, each of which is got from the original by differentiating the elements of one column, we have

$$\frac{\partial U}{\partial x} = \frac{1}{4!} \overset{+}{\begin{vmatrix} a_1 & u_1 & u_1 & \overset{+}{u_1} \\ a_2 & u_2 & u_2 & u_2 \\ a_3 & u_3 & u_3 & u_3 \\ a_4 & u_4 & u_4 & u_4 \end{vmatrix}} + \frac{1}{4!} \overset{+}{\begin{vmatrix} u_1 & a_1 & u_1 & \overset{+}{u_1} \\ u_2 & a_2 & u_2 & u_2 \\ u_3 & a_3 & u_3 & u_3 \\ u_4 & a_4 & u_4 & u_4 \end{vmatrix}} + \dots ;$$

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and, as the four permanents here are equivalent, this gives us

$$\frac{\partial U}{\partial x} = \frac{1}{3!} \begin{vmatrix} a_1 & u_1 & u_1 & u_1 \\ a_2 & u_2 & u_2 & u_2 \\ a_3 & u_3 & u_3 & u_3 \\ a_4 & u_4 & u_4 & u_4 \end{vmatrix}.$$

From this also it is clear that the expressions for $\partial U/\partial y$, $\partial U/\partial z$, $\partial U/\partial w$ can only differ from that for $\partial U/\partial x$ in having b's, c's, or d's in the first column in place of a's.

Proceeding now to a second differentiation, we first obtain in the same way

$$\frac{\partial^2 U}{\partial x^2} = \frac{1}{3!} \begin{vmatrix} a_1 & a_1 & u_1 & u_1 \\ a_2 & a_2 & u_2 & u_2 \\ a_3 & a_3 & u_3 & u_3 \\ a_4 & a_4 & u_4 & u_4 \end{vmatrix} + \frac{1}{3!} \begin{vmatrix} a_1 & u_1 & a_1 & u_1 \\ a_2 & u_2 & a_2 & u_2 \\ a_3 & u_3 & a_3 & u_3 \\ a_4 & u_4 & a_4 & u_4 \end{vmatrix} + \ldots,$$

and thence as before

$$\frac{\partial^2 U}{\partial x^2} = \frac{1}{2!} \begin{vmatrix} a_1 & a_1 & u_1 & u_1 \\ a_2 & a_2 & u_2 & u_2 \\ a_3 & a_3 & u_3 & u_3 \\ a_4 & a_4 & u_4 & u_4 \end{vmatrix}.$$

Further, had the second differentiation been performed with respect to another variable than x, it is clear that we should have had

$$\frac{\partial^2 U}{\partial x \, \partial y} = \frac{1}{2!} \begin{vmatrix} a_1 & b_1 & u_1 & u_1 \\ a_2 & b_2 & u_2 & u_2 \\ a_3 & b_3 & u_3 & u_3 \\ a_4 & b_4 & u_4 & u_4 \end{vmatrix}, \quad \frac{\partial^2 U}{\partial x \, \partial z} = \ldots$$

Not only so, but the result of a third differentiation can be foreseen, for example,

$$\frac{\partial^3 U}{\partial x^2 \partial z} = \begin{vmatrix} a_1 & a_1 & c_1 & u_1 \\ a_2 & a_2 & c_2 & u_2 \\ a_3 & a_3 & c_3 & u_3 \\ a_4 & a_4 & c_4 & u_4 \end{vmatrix},$$

and with equal ease the result of a fourth differentiation, for example,

$$\frac{\partial^4 U}{\partial x \, \partial y \, \partial z \, \partial w} = \begin{vmatrix} a_1 & b_1 & c_1 & d_1 \\ a_2 & b_2 & c_2 & d_2 \\ a_3 & b_3 & c_3 & d_3 \\ a_4 & b_4 & c_4 & d_4 \end{vmatrix}.$$

Of this last statement we have a verification in the fact that the definition of $\overset{+}{|}\, a_1 b_2 c_3 d_4 \overset{+}{|}$ corresponding to the Grassmann implied definition of a determinant is that *it is the coefficient of* xyzw *in the product* $u_1 u_2 u_3 u_4$.

3. The general theorem, which includes all the preceding results, and of which the validity can manifestly be attested to any further desired extent, may be definitely stated as follows :—

If the product of the n *linear functions of* n *variables,*

$$
\begin{aligned}
&a_1 x + b_1 y + c_1 z + \ \ldots \ . \\
&a_2 x + b_2 y + c_2 z + \ \ldots \ . \\
&a_3 x + b_3 y + c_3 z + \ \ldots \ . \\
&\ \ . \quad . \quad . \quad . \quad . \quad . \quad .
\end{aligned}
$$

be differentiated in all σ *times, namely,* p *times with respect to* x, q *times with respect to* y, r *times with respect to* z, *and so forth, the result is* $\dfrac{1}{(n-\sigma)!}$ *multiplied by the permanent got by repeating in it the first column of the conjugate of* $|a_1 b_2 c_3 \ldots .|$ p *times, the second column* q *times, the third column* r *times, and so forth, each of the remaining* n-σ *columns being filled with the column of* u's.

4. The equality which originally suggested the foregoing possesses also an interest of its own. It is

$$
| a_1\ b_2\ c_3 |^{\,2} \cdot \begin{vmatrix} \cdot & u_3 \cdot u_2 \\ u_3 & \cdot & u_1 \\ u_2 & u_1 & \cdot \end{vmatrix} = \begin{vmatrix} \overset{+}{|} a_1\, a_2\, u_3 \overset{+}{|} & \overset{+}{|} a_1\, b_2\, u_3 \overset{+}{|} & \overset{+}{|} a_1\, c_2\, u_3 \overset{+}{|} \\ \overset{+}{|} b_1\, a_2\, u_3 \overset{+}{|} & \overset{+}{|} b_1\, b_2\, u_3 \overset{+}{|} & \overset{+}{|} b_1\, c_2\, u_3 \overset{+}{|} \\ \overset{+}{|} c_1\, a_2\, u_3 \overset{+}{|} & \overset{+}{|} c_1\, b_2\, u_3 \overset{+}{|} & \overset{+}{|} c_1\, c_2\, u_3 \overset{+}{|} \end{vmatrix}
$$

and is readily verified on multiplying columnwise

$$
\begin{vmatrix} \cdot & u_3 & u_2 \\ u_3 & \cdot & u_1 \\ u_2 & u_1 & \cdot \end{vmatrix} \quad \text{by} \quad \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}
$$

and then using the result

$$
\begin{vmatrix} a_2 u_3 + a_3 u_2 & b_2 u_3 + b_3 u_2 & c_2 u_3 + c_3 u_2 \\ a_1 u_3 + a_3 u_1 & b_1 u_3 + b_3 u_1 & c_1 u_3 + c_3 u_1 \\ a_1 u_2 + a_2 u_1 & b_1 u_2 + b_2 u_1 & c_1 u_2 + c_2 u_1 \end{vmatrix}
$$

to multiply columnwise

$$
\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix} .
$$

5. The equality, of course, holds when the *a*'s, *b*'s, *c*'s, *u*'s are any quan-

tities whatever ; but its interest is considerably enhanced when the u's are taken equal to

$$a_1 x + b_1 y + c_1 z, \quad a_2 x + b_2 y + c_2 z, \quad a_3 x + b_3 y + c_3 z,$$

for then the right-hand member is *the Hessian of the product of the* u's, and the equality leads up to an important result.

To make this quite clear let us go back to U, the product of u_1, u_2, u_3, u_4 in § 2, and seek to obtain the Hessian of U. From the definition and the results of § 2 we have at once

$$H(U) = \begin{vmatrix} \tfrac{1}{2} \lvert a_1 a_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert a_1 b_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert a_1 c_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert a_1 d_2 u_3 u_4 \rvert \\ \tfrac{1}{2} \lvert b_1 a_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert b_1 b_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert b_1 c_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert b_1 d_2 u_3 u_4 \rvert \\ \tfrac{1}{2} \lvert c_1 a_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert c_1 b_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert c_1 c_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert c_1 d_2 u_3 u_4 \rvert \\ \tfrac{1}{2} \lvert d_1 a_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert d_1 b_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert d_1 c_2 u_3 u_4 \rvert & \tfrac{1}{2} \lvert d_1 d_2 u_3 u_4 \rvert \end{vmatrix}.$$

A little examination of this determinant shows that besides the factor 2^{-4} we can in a different way remove the determinant-factor $\lvert a_1 b_2 c_3 d_4 \rvert$, the cofactor left being

$$\begin{vmatrix} \lvert a_2 u_3 u_4 \rvert & \lvert b_2 u_3 u_4 \rvert & \lvert c_2 u_3 u_4 \rvert & \lvert d_2 u_3 u_4 \rvert \\ \lvert a_1 u_3 u_4 \rvert & \lvert b_1 u_3 u_4 \rvert & \lvert c_1 u_3 u_4 \rvert & \lvert d_1 u_3 u_4 \rvert \\ \lvert a_1 u_2 u_4 \rvert & \lvert b_1 u_2 u_4 \rvert & \lvert c_1 u_2 u_4 \rvert & \lvert d_1 u_2 u_4 \rvert \\ \lvert a_1 u_2 u_3 \rvert & \lvert b_1 u_2 u_3 \rvert & \lvert c_1 u_2 u_3 \rvert & \lvert d_1 u_2 u_3 \rvert \end{vmatrix},$$

as is readily verified on multiplying $\lvert a_1 b_2 c_3 d_4 \rvert$ columnwise by the latter. From this again in the same fashion a second $\lvert a_1 b_2 c_3 d_4 \rvert$ can be removed as a factor, the remaining cofactor being

$$\begin{vmatrix} \cdot & 2u_3 u_4 & 2u_2 u_4 & 2u_2 u_3 \\ 2u_3 u_4 & \cdot & 2u_1 u_4 & 2u_1 u_3 \\ 2u_2 u_4 & 2u_1 u_4 & \cdot & 2u_1 u_2 \\ 2u_2 u_3 & 2u_1 u_3 & 2u_1 u_2 & \cdot \end{vmatrix},$$

as is seen this time by multiplying the latter rowwise by $\lvert a_1 b_2 c_3 d_4 \rvert$. On having its rows multiplied by u_1, u_2, u_3, u_4 respectively, the zero-axial determinant thus arrived at becomes divisible by $2u_2 u_3 u_4$, $2u_1 u_3 u_4$, $2u_1 u_2 u_4$, $2u_1 u_2 u_3$, leaving a type of determinant which when of the nth order is equal to $(-1)^{n-1}(n-1)$. There thus results

$$H(U) = (-1)^3 \cdot 3 \cdot (u_1 u_2 u_3 u_4)^2 \cdot \lvert a_1 b_2 c_3 d_4 \rvert^2,$$

—a known equality which has already been established otherwise.

RONDEBOSCH, S.A.,
27th May 1923.

NOTES ON SOME SOUTH AFRICAN XYLARIAS.

By Prof. Paul A. Van der Bijl.

In Vol. IX, p. 181, of the Transactions of the Royal Society of South Africa, I gave the descriptions of four Xylaria species known to occur in South Africa. Since then additional species have been collected, and we give below the descriptions of these additional species, together with brief notes which may be of assistance in recognising and distinguishing them.

The numbers quoted in brackets are the herbarium numbers of my collection at the University of Stellenbosch.

Xylaria Castorea, Berk.

Plants epixylous, often fasciculate, solid, black externally, white internally, 1·5–4 cms. high; stalk 17 mm. or less long, black, spongy-velutinous; clubs subglobose or subelliptical, frequently much compressed, surface roughened by the prominent osticles; perithecia globose; asci narrow; spores brown, ovoid-oblong, straight to slightly curved, $8–10 \times 4\mu$.

On dead wood, Durban, Natal (795).

This species belongs to the "*polymorpha*" section. It can be distinguished from the majority of other species belonging to that section by its comparatively *small spores*.

Xylaria Corniformis, Fr.

Plants epixylous, usually occurring singly, solid, black externally, white internally; stalk short, arising from a thick, *swollen base*; clubs cylindrical, rarely flattened, 4 cms. high; perithecia globose; spores brown, $8–12 \times 4–5\mu$.

On dead wood, Knysna, Cape Province. Collected by Miss A. V. Duthie (1103).

This species can be easily recognised by its *swollen base*. In this character it differs from *Xylaria polymorpha*. Its spores also are smaller and the plants usually occur singly.

Xylaria Tabacina, Kickx.

Plants epixylous, frequently fasciculate, light brown externally, white internally, central internal tissue disappears leaving a hollow surrounded by firm white tissue, external to which is the light-brown, outer pellicle ; stalk ·5–5 cm. long, glabrous, light brown ; clubs cylindrical or oval, 2–8·5 cms. high, frequently compressed, splitting when the internal tissue disappears ; surface light brown, rugulose in dried material, dotted with the ostioles of the perithecia ; perithecia globose ; asci narrow ; spores brown, straight to slightly curved, 20–24 ×8μ.

On dead wood, Knysna, Common (710 and 1104).

This species is distinguishable superficially from others occurring in the Union by its light-brown colour.   It was originally named from Mexico.

Xylaria Variabilis, Currey.

Plants epixylous, frequently fasciculate, greyish black externally, white internally ; in old specimens the interior tissue disappears ; stalk black, glabrous ; clubs cylindrical unbranched or branched, frequently compressed, 4–7 cms. high ; surface greyish, with black lines roughened by the protruding ostioles ; perithecia globose ; spores brown, ovoid-oblong, straight to slightly curved ; 10–12 ×4–5μ.

On a burnt stump, Durban, Natal (771).

This species can be distinguished from other South African species by the *dark lines on the greyish clubs.*

The American species *Xylaria grammica* has similar lines to the above, and it may be that they are the same species.   *Xylaria variabilis* is said to be a more slender plant.

Note.—In addition to the species already mentioned, I have also *Xylaria Schweinitzii*, Berk and Curtis (probably but a form of *Xylaria polymorpha*), from Knysna, and *Xylaria myosurus*, Mont., from Eshowe, Zululand.   My material of the above two species has no spores, and I prefer to wait with them until better material is procured.

Several collections of Xylarias were in their conidial stages only, and these could hence not be specifically identified.

LABORATORY OF PHYTOPATHOLOGY AND MYCOLOGY,
THE UNIVERSITY OF STELLENBOSCH,
UNION OF SOUTH AFRICA.

ON THE ATTRACTION-COEFFICIENT FOR SUBSTANCES OF LOW CRITICAL TEMPERATURE.

By John P. Dalton,

University of the Witwatersrand.

§ 1. Introduction.

The question of the dependence of the Van der Waals "a" upon temperature has received considerable attention from various writers on thermodynamics.* Some years ago† the present writer, using Young's saturation data for isopentane,‡ found that for this substance the dependence of a upon temperature is given by

$$a = a_k e^{\beta(T_k - T)} \qquad . \qquad . \qquad . \qquad . \qquad . \quad (1)$$

within the reduced temperature region $\theta = 0.6$ to $\theta = 1$. The value of β for isopentane was found to be 2.45×10^{-3}, and therefore $\beta T_k = 1.127$.

At the time sufficient saturation data were not available to allow of the testing of this law of dependence and the determination of the corresponding constants for other substances, and consequently βT_k was taken to be unity as a first approximation.§ Since then, however, the brilliant researches of Kamerlingh Onnes and his collaborators at Leiden have rendered available accurate saturation data for various substances of low critical temperature ; and in the present paper their results have been utilised to determine the constants of the relation (1) for argon, oxygen, nitrogen, and hydrogen.

§ 2. Method of Calculation.

The same method of calculation has been employed as in the case of isopentane. The change of internal energy between saturated liquid and saturated vapour is

$$e_2 - e_1 = \left(T \frac{dp}{dT} - p \right)(v_2 - v_1) = \int_{v_1}^{v_2} \left(T \frac{\partial p}{\partial T_v} - p \right) dv \qquad . \qquad . \quad (2)$$

---

* For literature see Kamerlingh Onnes and Keesom, " Die Zustandsgleichung," Encyk. Math. Wiss., v, 10, § 48.

† J. P. Dalton, Trans. R.S.S.A., iv, 123 (1914).

‡ S. Young, Proc. Phys. Soc., xiii, 602 (1895).

§ *Cf.* Van der Waals, Kontinuität, ii, 174 (1900).

Applying this to the Van der Waals equation

$$\left(p+\frac{a}{v^2}\right)(v-b)=\mathrm{R}\mathrm{T} \qquad . \qquad . \qquad . \qquad . \qquad (3)$$

where a is regarded as a function of the temperature and b as independent of the temperature, and integrating from the critical temperature, we get

$$\frac{a}{\mathrm{T}}=\left(\frac{a}{\mathrm{T}}\right)_k+\int_{\mathrm{T}_k}^{\mathrm{T}}\frac{v_1 v_2}{\mathrm{T}^2}\left(\mathrm{T}\frac{dp}{d\mathrm{T}}-p\right)d\mathrm{T} \qquad . \qquad . \qquad . \qquad (4)$$

From (3) it follows that the constant of integration $\left(\dfrac{a}{\mathrm{T}}\right)_k$ is $\dfrac{3p_k}{\mathrm{T}_k\rho_k^2}$ where ρ_k is the critical density.

For a successful application of (4) a knowledge is required of the critical constants, of the saturation volumes (or densities), and of the dependence of vapour pressure on temperature ; and any uncertainty affecting these factors will influence the resulting values of a. In the case of the substances here discussed critical pressure and temperature are very accurately known, but some uncertainty affects the value of the critical density. In the neighbourhood of the critical point the integral on the right of (4) is small compared with the constant of integration, and consequently an uncertainty in the value of ρ_k will have considerable influence upon the derived values of a in that region ; hence the selection of the value of ρ_k to be used is a matter of importance.

The critical density may be obtained from the relation $\dfrac{\partial p}{\partial \mathrm{T}_{vk}}=\dfrac{dp}{d\mathrm{T}_k}$, but values thus derived depend upon the differentiation of an empirical formula for p at an end-point of its domain of definition, and must therefore be regarded with some suspicion. The critical density may also be obtained by extrapolation of the " diameter," which gives the mean density of saturated liquid and saturated vapour as a function of the temperature. To a high degree of approximation this diameter is a straight line, but in the neighbourhood of the critical point small deviations occur * which cast some doubt upon values obtained by linear extrapolation. In the case of argon, for example, Crommelin † found for the critical density, by equating the critical pressure-coefficients, $\rho_k=0.509$; while linear extrapolation of the diameter ‡ gave 0·53078, and quadratic extrapolation gave § 0·5296. As the critical density is in any case an extrapolated value, it has been

* See, *e.g.*, article by E. Mathias in Gedenkboek aangeboden aan H. Kamerlingh Onnes, Leiden (1922).

† C. A. Crommelin, Comm. Leiden, No. 118*a* (1910).

‡ Mathias, Kamerlingh Onnes, and Crommelin, Comm. Leiden, No. 131*a* (1912).

§ E. Mathias, *loc. cit.*, p. 183.

judged best to use those values given by quadratic extrapolation of the
diameter for the present calculations.

With regard to other uncertainties, the possible error in calculated values
of $\dfrac{dp}{dT}$ is unimportant except in the immediate neighbourhood of the critical
point, but, on the other hand, in that neighbourhood the integral on the
right of (4) is small compared with $\left(\dfrac{a}{T}\right)_k$. In the data used for saturation
densities those of the liquid are given to four or more significant figures ;
but at the lower temperatures the saturated vapour densities are given to
only two significant figures. As in the investigations for which these
densities were determined only their sum was involved, this degree of
uncertainty in the vapour density was immaterial ; but in the present
calculations, where we are concerned with the product of the two densities, it
becomes significant, and the calculations are accordingly extended only to
those densities which are given to within one per cent.

§ 3. DATA.

The following data have been used :—

(a) *Critical Constants.*

Substance.	Crit. temp.	Crit. press.	Crit. dens.*	$\left(\dfrac{a}{T}\right)_k$
	° K.	Atm.	gr./cm.^{3}	
Argon † .	150·65	47·996	0·5296	3·4077
Oxygen ‡	154·27	49·713	0·4315	5·1940
Nitrogen ‡	125·96	33·490	0·3155	8·0132
Hydrogen §	33·18	12·80	0·03104	1201·2

(b) *Vapour Pressure Formula.*

Common Logarithms ; Pressures in Atmospheres.

Argon ‖ $\log p = 4 \cdot 85033 - 634 \cdot 391 T^{-1} + 30769 \cdot 09 T^{-2}$
$- 1076464 T^{-3}$

Oxygen $\log p = 4 \cdot 57472 - \dfrac{508 \cdot 645}{T + 22 \cdot 45}$

* E. Mathias, *loc. cit.* p. 183.
† C. A. Crommelin, Comm. Leiden, No. 115 (1910).
‡ Onnes, Dorsman, and Holst, Comm. Leiden, No. 145*b* (1914).
§ Onnes, Crommelin, and Cath, Comm. Leiden, No. 151*c* (1917).
‖ C. A. Crommelin, Comm. Leiden, No. 138*c* (1913).

Nitrogen * $\log p = 5 \cdot 76381 - 853 \cdot 522 T^{-1} + 54372 \cdot 3 T^{-2}$
$$- 1783500 T^{-3}$$

Hydrogen † $\log p = -56 \cdot 605 T^{-1} + 3 \cdot 8015 - 0 \cdot 10458 T$
$$+ 0 \cdot 003321 T^2 - 0 \cdot 00003219 T^3.$$

In the case of oxygen, Holst ‡ and Cath § have given vapour pressure formulæ for the region below the boiling-point, but these will not stand extrapolation up to the critical point. Hence the foregoing oxygen formula was specially calculated from the observations of Kamerlingh Onnes, Dorsman, and Holst,‖ covering the region from 118° K. to the critical point. The formula was adjusted to the two end-points of the range and a value near the centre, and as the agreement with the experimental pressures was sufficient for the present purpose, no further adjustment of the constants was attempted. The greatest divergence between observed and calculated values of p is 0·6 per cent., and this compares favourably with the agreement given by more elaborate formulæ.

§ 4. Results of Integration.

The following tables give the integrand of (4) as computed from the appropriate vapour pressure formula and from the saturation densities obtained from the sources indicated in the references below :—

TABLE I.—*Argon.*¶

T.	Integrand.	Integral.	T	Integrand.	Integral.
89·94	0·1181	..	130	..	0·9539
90	..	4·2811	132·89	0·0513	..
97·70	0·1023	..	137·58	0·0479	..
100	..	3·2017	140	..	0·4521
110	..	2·3018	141·55	0·0458	..
111·86	0·0785	..	147·92	0·0406	..
120	..	1·5586	150	..	0·0233
122·33	0·0650	..	150·65	0·0377	0·0000

The lowest vapour density (at 89°·94) is 0·00801, and all the available data have therefore been used.

* C. A. Crommelin, Comm. Leiden, No. 145d (1914).
† Cath and Kamerlingh Onnes, Comm. Leiden, No. 152a (1917).
‡ G. Holst, Comm. Leiden, No. 148a (1915).
§ P. G. Cath, Comm. Leiden, No. 152d (1918).
‖ Onnes, Dorsman, and Holst, Comm. Leiden, No. 145b (1914).
¶ Mathias, Onnes, and Crommelin, Comm. Leiden, No. 131a (1912).

TABLE II.—*Oxygen.**

T.	Integrand.	Integral.	T.	Integrand.	Integral.
118·58	0·1053	..	143·19	0·0776	..
120	..	2·8238	145	..	0·6118
125	..	2·3270	149·79	0·0670	..
130	..	1·8618	150	..	0·2554
132·89	0·0877	..	152·69	0·0572	..
135	..	1·4211	154·27	0·0542	0·0000
140	..	1·0034			

In the case of oxygen the density values are given at somewhat wider temperature intervals than for the other substances under investigation. There was therefore some little dubiety regarding the course of the curve of the integrand. The point of inflection which all these curves exhibit was further from the critical point than usual, which may be due to the fact that the point next the critical point lay somewhat off the curve. In the density data two more values are given at 91° and 63°, but as the vapour densities are given to less than three significant figures at these points they have not been used.

TABLE III.—*Nitrogen.*†

T.	Integrand.	Integral.	T.	Integrand.	Integral.
67·64	0·5036	..	110	..	2·2132
70	..	13·2838	111·89	0·1570	..
73·06	0·4306	..	119·44	0·1338	..
78·00	0·3725	..	120	..	0·7402
80	..	9·2804	123·34	0·1206	..
90	..	6·3224	124·48	0·1168	..
90·58	0·2510	..	125	..	0·1070
99·36	0·2069	..	125·01	0·1153	..
100	..	4·0358	125·96	0·1057	0·0000

An additional point at 65°, for which the vapour pressure is given to only two significant figures, has not been used.

* Mathias and Kamerlingh Onnes, Comm. Leiden, No. 117 (1910).

† Mathias, Kamerlingh Onnes, and Crommelin, Comm. Leiden, No. 145c (1914).

TABLE IV.—*Hydrogen.*[*]

T.	Integrand.	Integral.	T.	Integrand	Integral.
[20·41	125·3]	. .	29	. .	232·8
23	. .	721·3	30·06	58·52	. .
23·20	98·31	. .	31	. .	110·8
25	. .	535·2	31·26	54·71	. .
25·30	85·04	. .	32·52	49·05	. .
27	. .	373·2	33	. .	7·9
27·36	73·16	. .	33·18	42·77	0·0
28·79	66·60				

In the reference quoted below there is also given a series of densities ranging from 20° down to 15°. For these, however, only the liquid densities were measured, the vapour densities being calculated; and, moreover, the significance of these calculated densities below 19° is less than one per cent. Hence only the actual measured values were used for the present purpose; but one value of the integrand was calculated from the second series of densities (20°·41) for the purpose of indicating the course of the integrand between 23° and 25°, and is given above.

§ 5. THE DEPENDENCE OF a UPON T.

Combining the integrals just given with the appropriate values of $\left(\dfrac{a}{T}\right)_k$ from § 3, we find that for the four substances under investigation a can well be represented as an exponential function of the temperature, and the following tables give comparisons between the values of a derived from the experimental data in the manner shown, and those yielded by an equation of the type $\log a = \alpha - \beta T$.

TABLE V.—*Argon* (fig. 1).

T.	a (exp.).	a (cal.).	T.	a (exp.).	a (cal.).
90	692·0	692·9	130	567·0	568·1
100	660·9	659·3	140	540·4	540·6
110	628·0	627·4	150	514·6	514·5
120	596·0	597·0	150·65	513·4	512·9

$$\log_e a = 6·9875 - 0·004963T$$

* Mathias, Crommelin and Kamerlingh Onnes, Comm. Leiden, No. 154*b* (1921).

FIG. 1.

ARGON
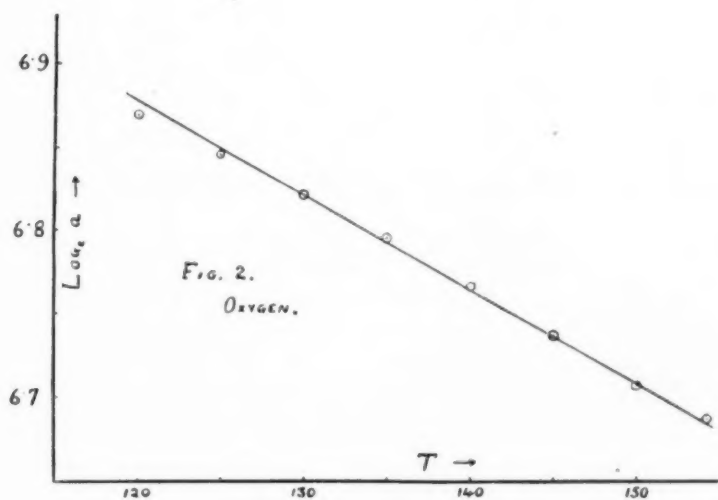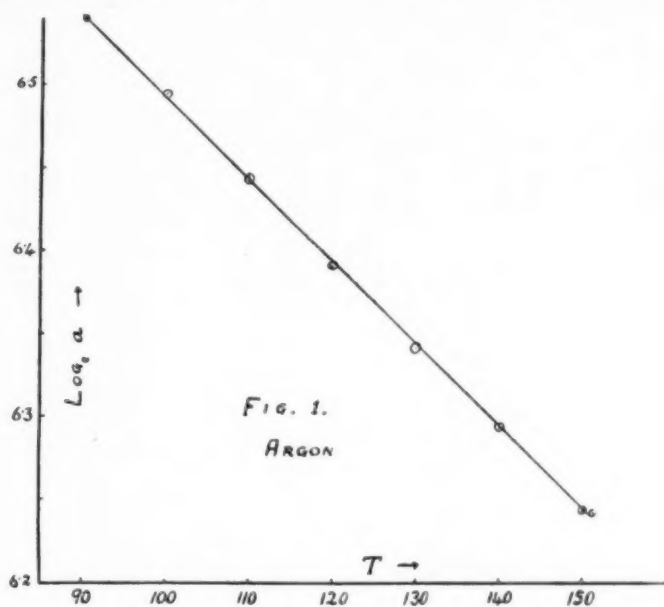
FIG. 2.

OXYGEN.

TABLE VI.—*Oxygen* (fig. 2).

T.	a (exp.).	a (cal.).	T.	a (exp.).	a (cal.).
120	962·3	970·0	140	867·6	865·7
125	940·2	942·8	145	842·0	841·4
130	917·1	916·4	150	817·3	817·8
135	892·9	890·7	154·27	801·3	798·4

$$\log_e a = 7\cdot5600 - 0\cdot005689T$$
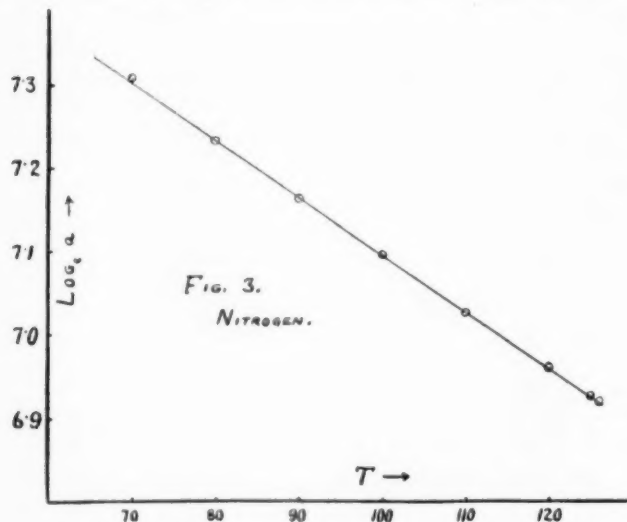
FIG. 3.
NITROGEN.

TABLE VII.—*Nitrogen* (fig. 3).

T.	a (exp.).	a (cal.).	T.	a (exp.).	a (cal.).
70	1491	1480	110	1125	1125
80	1384	1382	120	1050	1051
90	1290	1291	125	1015	1015
100	1205	1205	125·96	1009	1011

$$\log_e a = 7\cdot7807 - 0\cdot006863T$$

TABLE VIII.—*Hydrogen* (fig. 4).

T.	a (exp.).	a (cal.).	T.	a (exp.).	a (cal.).
23	44,220	44,320	31	40,690	40,760
25	43,420	43,400	33	39,990	39,910
27	42,540	42,500	33·18	39,860	39,840
29	41,610	41,620			

$$\log_e a = 10 \cdot 940 - 0 \cdot 01047T$$

FIG. 4.
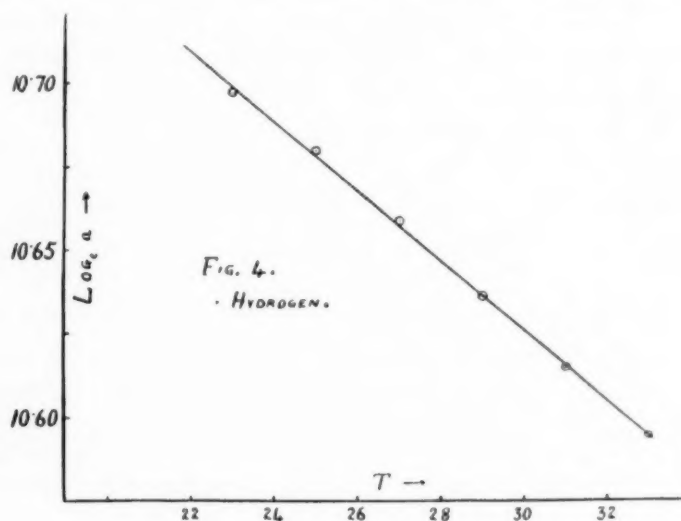
· HYDROGEN.

TABLE IX.—*The Attraction-coefficient.*

	$\beta \times 10^3$	βT_L.
Isopentane . .	2·446	1·127
Argon . . .	4·963	0·7477
Oxygen . . .	5·689	0·8776
Nitrogen . .	6·863	0·8644
Hydrogen . .	10·47	0·3474

From the foregoing results it is clear that, within the ranges of temperature considered, the exponential law of dependence of a upon T which was found for isopentane, holds likewise for the substances now discussed. But the product βT_k deviates considerably from unity, and the assumption previously made * regarding the constancy of βT_k must be discarded. Indeed, it appears as if the coefficient β, which, since $\beta = -\dfrac{1}{a}\dfrac{da}{dT}$, may be termed the specific attraction temperature-coefficient, might provide a measure for deviations from the law of corresponding states at least in the neighbourhood of the saturation region. From the material at present available it appears that β diminishes as the molecular weight of the substance increases.

§ 6. ATTRACTION-COEFFICIENT AND CRITICAL-PRESSURE COEFFICIENTS.

From equations (1) and (3) we get

$$\frac{T}{p}\frac{\partial p}{\partial T_v} = 1 + (1+\beta T)\frac{a_k e^{\beta(T_k - T)}}{pv^2} \qquad . \qquad . \qquad . \qquad (5)$$

and therefore the critical pressure coefficient is

$$K_5\left[= \frac{T_k}{p_k}\left(\frac{\partial p}{\partial T_v}\right)_k \right] = 4 + 3\beta T_k \qquad . \qquad . \qquad . \qquad (6)$$

On thermodynamical grounds the critical pressure coefficient must be the same as the critical vapour-pressure coefficient $K_6 = \dfrac{T_k}{p_k}\left(\dfrac{dp}{dT}\right)_k$; hence either K_5 or K_6 ought to suffice for the determination of β. If we compute K_6 from the vapour-pressure formulæ of § 3 we obtain the following values, which lead to values of β consistently lower than those obtained in the previous section :—

TABLE X.

	K_6.	$10^3\beta$ from K_6.	$10^3\beta$ from § 4.
Argon . .	5·6275	3·601	4·963 †
Oxygen . .	5·7855	3·858	5·689
Nitrogen .	5·9854	5·254	6·863
Hydrogen .	4·6531	6·561	10·470

* J. P. Dalton, *loc. cit.*

† Crommelin (Thesis for Doctorate, Leiden, 1910) gives $K_6 = 5·712$, using a different vapour-pressure formula. This would give $10^3\beta = 3·788$.

It is well known that the thermodynamical relation $K_5 = K_6$ is not satisfied by experimentally determined values of these coefficients. K_5 is consistently larger than K_6 (and would therefore yield larger values of β) and the difference is sometimes ascribed to uncertainty in the value of the critical volume. But the foregoing results raise a question regarding the accuracy of the limiting value of $\dfrac{dp}{dT}$ at the critical point found from the empirical vapour pressure formula, and some further enquiry seems desirable.

Measurements by Onnes, Crommelin, and Cath * of the vapour pressure of hydrogen in the immediate neighbourhood of the critical point afford an opportunity of considering the question more closely. Their determinations of the vapour pressure, together with the corresponding values calculated from the formula of § 3, are as follows :—

T.	p obs.	p cal.	obs.—cal.	$\dfrac{\Delta p}{\Delta T}$ obs.	$\dfrac{\Delta p}{\Delta T}$ cal.
32·02	10·825	10·795	+0·030		
				1·60	1·65
32·60	11·752	11·750	+0·002		
				1·73	1·72
32·93	12·322	12·317	+0·005		
				1·91	1·73
33·18	12·80	12·75	+0·05		

From these it appears that although the empirical formula gives very satisfactory agreement between calculated and observed pressures, yet it gives a very much flatter curve in the immediate neighbourhood of the critical point. Of course, the last value of $\dfrac{\Delta p}{\Delta T}$ may be seriously affected by uncertainty in the critical pressure, which is itself an extrapolated value, and unless some further support can be found for larger values of $\dfrac{dp}{dT}$ near the critical point, there would seem to be no valid reason for rejecting values of K_6 calculated from the empirical formulæ. In order to throw additional light on the matter the foregoing values of p and T were plotted, and tangents drawn to the curve at various points near the critical. Column 2 of the following table gives the values of $\dfrac{dp}{dT}$ thus obtained, and column 3 the corresponding values computed from the vapour pressure formula of § 3.

* Comm. Leiden, No. 151c (1917).

T.	$\frac{dp}{dT}$ graph.	$\frac{dp}{dT}$ calc. I.	$\frac{dp}{dT}$ calc. II.
32·8	1·74	1·73	1·78
32·9	1·81	1·74	1·82
33·0	1·87	1·76	1·85
33·1	1·92	1·78	1·89
33·18	1·955	1·795	1·92

The graphical method is certainly rough, but it seems to confirm the smallness of the values of $\frac{dp}{dT}$ as computed from the vapour-pressure formula of § 3. Graphical extrapolation of $\frac{dp}{dT}$ to the critical temperature gave $\left(\frac{dp}{dT}\right)_k = 1\cdot955$. This would make $K_6 = 5\cdot068$, and $10^3\beta = 10\cdot73$, a value that is much closer to that obtained from the saturation data.

Various attempts were made to fit an empirical curve to the observations near the critical point. Of these the most satisfactory proved to be

$$\log_{10}\log_{10} p = -0\cdot805314 + 0\cdot025605T$$

which fits the observations thus :—

T.	p (obs.).	p (cal.).	obs.—cal.
32·02	10·825	10·817	+0·008
32·60	11·752	11·751	+0·001
32·93	12·322	12·334	−0·012
33·18	12·80	12·802	−0·002

From this formula the values given in the fourth column of the previous table were calculated for $\frac{dp}{dT}$, and they afford a certain amount of confirmation of the graphical deductions. This formula gives $K_6 = 4\cdot988$, which is considerably higher than that obtained from the full vapour pressure formula. The mean of this value and that obtained graphically is 5·028, which makes $10^3\beta = 10\cdot33$, in fair agreement with that obtained from the saturation data.

It would appear, therefore, as if the discrepancies noted in Table X may legitimately be ascribed to uncertainty in the values of K_6, and that therefore the values for the attraction coefficient here deduced may be considered valid for the vicinity of the saturation region.

June 7th, 1923.

THE ACTION-CURRENT ACCOMPANYING REFLEX ACTIVITY OF MUSCLE IN THE SOUTH AFRICAN CLAWED FROG.

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(With Plate II and three Text-figures.)

In the course of an investigation on reflex times in the South African clawed frog, with the object of determining the delay associated with the passage of the nerve impulse from one neurone to another within the spinal cord and the rhythm of discharge of the motor neurones, I have had occasion to make many hundreds of records of the electrical variation accompanying contraction of the gastrocnemius muscle thrown reflexly into action. The method of record has been to wind the cotton wicks of the non-polarisable electrodes round the lower limb over the intact skin, one below the knee covering the skin over the muscle from its upper end to about the middle, and the other at the ankle over the tendon. Before applying the wicks the anterior surface of the limb is covered with a piece of sheet-rubber to prevent any action of muscles other than the gastrocnemius from affecting the galvanometer. The wicks, soaked in salt solution, are secured in place by thread wound round the limb. The Einthoven String Galvanometer has been used to record the electrical variation.

The present paper embodies the result of an attempt to elucidate further the form of the reflex response of muscle and the question whether, and if so, at what rate, successive impulses reach it from the motor neurones when the stimulus is a single mechanical one.

The form of a muscle's action-current is very susceptible to alteration by any injury or interference with the normal conditions of circulation, etc., and the method here used should give us a favourable opportunity of studying the form without distortion, since the frogs are used after the wound caused by transection of the spinal cord has healed and they are capable of living for six or seven months afterwards.

The skin over the muscle is intact at the time of experiment and the circulation undisturbed.

We may expect to obtain further light on the question whether the response of the uninjured muscle to a single stimulus is a simple diphasic deflection or whether it is of an oscillatory nature, as evidence which has been accumulating in recent years would seem to suggest.

The view that the muscular effector organ may exhibit an inherent rhythm of action independent of any rhythm of impulses reaching it through the motor nerve, which was urged by Buchanan (1), is gaining ground, and it is probable that the response of the gastrocnemius under normal conditions to a single induction shock applied to its nerve is very frequently if not always more like a repetitive or oscillatory variation than a single diphasic deflection.

My own experience with the isolated gastrocnemius and sciatic nerve is in favour of this view.

Fig. 1 is the electrical response of the gastrocnemius of a nerve-muscle preparation to a break induction shock applied to the nerve. The wicks of the non-polarisable electrodes were applied one to the nervous equator of the muscle, the other to the tendon. The temperature was 19° C. It will be seen that the response is not a single diphasic deflection, but that, succeeding the first summit, other oscillations are visible.

As regards the reflex response to a single mechanical stimulus, I have figured in a previous paper (2) responses obtained from the gastrocnemius of the South African clawed frog thrown reflexly into action by a light mechanical hammer tap applied to the foot either of the same or of the opposite side. These responses are clearly oscillatory. Figs. 2 and 3, p. 40, of the previous paper, are records made at 20° C., and each shows three deflections decreasing in size. The intervals between the first and second summits in the two curves are 9 σ and 10·3 σ, while the interval between the second and third summits is 7·5 σ. I pointed out that these variations resemble the record of a twitch. In fig. 4, besides three initial deflections, resembling those of figs. 2 and 3, there are also evident on the negative, although barely visible in the reproduced curve, three small rapid oscillations beginning 30 σ after the commencement of the whole response, and the presence of these I took to indicate that in addition to a twitch there may also be an element of tonic contraction involved.

The conclusion to be drawn from these records is that the reflex movement of the hind limb in the spinal frog in response to a tap on the foot is frequently of the nature of a twitch and that the electrical counterpart of a twitch in the muscle is a series of oscillations.

On referring to the literature, we find that many observers have obtained, on using a single stimulus applied to the motor nerve, curves from frog muscle more complex than a single deflection. Thus it was shown by the

rheotome method (19) that triphasic variations are recorded from the uninjured muscle on indirect stimulation by single shocks.

More recently, Durig (3) has shown in frogs whose tissues have been rendered specially excitable by being deprived of water that a single induction shock elicits from the muscle not a single deflection but a series of rhythmical discharges. The duration of the waves as demonstrated by the capillary electrometer is from 8 to 15 σ.

Garten (4) and Dittler and Tichomirow (5), using not a single shock but the continuous stimulation of a galvanic current and employing a muscle whose excitability has not been artificially raised, find that the muscle responds by a series of rhythmical deflections which agree in period with those obtained by Durig. The period varies with temperature, the T. coefficient for 10° C. being 1·9245.

Brücke (6) found that the response of the sartorius in freshly caught healthy and strong specimens to a single shock was frequently of a periodic nature, consisting of a series of deflections like those found by Durig in the water-poor muscle. In one curve which this author figures, there are three summits, the interval between the first two summits being 9 σ and the interval between the second two being 7 σ. Brücke also quotes Garten and Hofmann as stating that they have sometimes observed rhythmical responses in the normal frog sartorius to single shocks. Brücke concludes from his findings and those of Durig that the muscle substance exhibits a specific rhythm.

Buchanan (1) has recorded cases where the action-current of the gastrocnemius shows more than one summit in response to a single strong indirect stimulus, the summits being separated by about 6 σ. This author is inclined to take the view that the phenomenon is dependent in some way on the arrangement of the fibres in the gastrocnemius which differs from that in the sartorius, but quotes Durig's work as suggesting another interpretation.

Dittler (7) found with the diaphragm of the warm-blooded animal that stimulation of the phrenic nerve with a single induction shock frequently gives rise to an oscillatory action-current in the muscle. The oscillatory response was found to be the rule with strong induction shocks. Also when the stimulus is given to the nerve secondarily from the beating ventricle, the muscular response is oscillatory in the great majority of cases, the curves closely resembling those given by the muscle in opening tetanus.

Piper (8) gives records of the electrical response of the human forearm to a single induction shock applied to the ulnar nerve. The leads on the forearm were 10 cm. distant from each other. On examining Piper's curves, *e.g.* fig. 11, p. 27, it will be seen that there is evidence of rhythmic action. This curve does not show a simple upward followed by a simple downward deflection. The upward deflection is really dicrotic.

Samojloff (9) also has figured the response from the human forearm, the leads being 8 cm. apart.   Here also, as in Piper's curves, we see that the phases are really dicrotic.   After the first negative (upward) deflection, *e.g.* in Plate viii, fig. A, *a*, a second small negative deflection makes itself evident about 3·5 σ after the first.   Samojloff draws attention to this second deflection which he marks with a star, and terms a slight distortion of the curve.

Judin (10) comes to the conclusion from his records of the response of frog's muscle to single induction shocks that the process occurring in active muscle has a periodic character.   He considers that the action-current corresponding to a single muscular contraction is not a single diphasic deflection, but consists of a series of four or five damped oscillations.   The first oscillation, which has a greater magnitude, has also a longer duration than the others, and its duration is dependent on temperature in accordance with van 't Hoff's law.   Further, as the temperature is lowered, the oscillatory character of the response tends to disappear and the curve becomes diphasic. The duration of the secondary oscillations, which is about 4·5 σ does not seem to be much affected by change of temperature.   This author does not consider that the diphasic character shown by some of the curves can be explained on the hypothesis of superposition of two single phasic currents, because, among other considerations, the method of leading off from the muscle and its tendon excludes this possibility.   Judin finds that a second stimulus gives rise to a second action-current when it is applied 3·6 σ after the first, but that when applied 2·7 σ after the first no second action-current is produced and the recorded curve remains identical with that obtained when one stimulus alone is given, and he considers that the period of inexcitability of the muscle lasts as long as is necessary for the first oscillation to reach its maximum (between 2·7 and 3·6 σ).

Beritoff (11) states that he himself never observed a tendency to rhythmic reaction in the muscle when he stimulated the motor nerve with a single induction shock, while rhythmical response was always present when the muscle was thrown into activity reflexly by a single induction shock applied to an afferent nerve, and this author is inclined to interpret the successive waves obtained under these conditions as the expression of the rhythm of discharge of the nervous centres.   But Beritoff recognises the force of the evidence contained in the literature in favour of the presence of an intrinsic rhythm in the muscle when responding to a momentary stimulus applied through the motor nerve, and states that the tendency to rhythmic excitation cannot in any way be regarded as an exclusive attribute of the central nervous system.

Henriques and Lindhard (12) record the action-current of the frog's gastrocnemius when one lead is applied to the muscle substance and the

other to the tendon. The nerve is stimulated by a single induction shock and the response is oscillatory.

As I shall show, my own records seem to give evidence of a peripheral intrinsic rhythm of the effector organ, and, in addition, to show in many cases that successive impulses are being sent out by the spinal centre in the reflex provoked by a single mechanical stimulus, and light is thrown on the rate at which these are being received by the muscle.

Figs. 2, 3, and 4 are records of the action-current of the gastrocnemius of the spinal frog in what may be called the chronic condition, *i.e.* after the wound caused by section of the cord has entirely healed. The muscle is here contracting reflexly in response to a light hammer tap applied to the opposite foot. The experiments, figs. 2 and 3, were performed at room T. in the month of May, and the gullet T. of the frog was 19° C.

Fig. 2 consists of a series of four oscillations. The average interval between the oscillations, measuring from summit to summit, is about 6·1 σ. Fig. 3 shows oscillations with an average interval between summits of about 5·9 σ.

Fig. 4 is the electrical response of the gastrocnemius of another frog at gullet T. of 14° C. recorded in the month of June. This curve shows at least four distinct oscillations with an average interval between the summits of about 5·6 σ.

In diagram fig. 8 there is seen in curve 1 another response of a similar regular form. This was obtained reflexly by mechanical stimulation of the same foot in the month of January at gullet T. of 20·5° C.

These curves are examples of a fairly regular rhythmic response, which resemble a series of diphasic deflections decreasing in amplitude, and they are similar to the curves obtained by Durig and by Judin. I am not disposed, with the evidence at present available, to consider that they give evidence of the rhythm of activity of the motor neurones, but rather that they are due to an intrinsic rhythm in the effector organ. The muscular effectors in my experiments, being under normal conditions of circulation, etc., will be more likely to yield fully developed rhythmic responses than in the case of exercised nerve-muscle preparations.

Responses of the form exhibited by these curves are by no means universally obtained in reflex contraction of the gastrocnemius. They are, in fact, not the most frequent. The response is usually more complicated than this, and if the regular form is to be ascribed to a peripheral rhythm set up by a single central discharge, then it is reasonable to suppose that the more complicated curves owe their form to interference caused by successive discharges from the centre.

Fig. 5 represents the most common type of response. This curve was obtained reflexly at room T. in the month of January, gullet T., 22·6° C.,

by mechanical stimulation of the homonymous foot. It will be seen that we have not here to do with a regular series of deflections decreasing in amplitude as in the previous curves, but that, shortly after the descending limb of the first deflection has reached and crossed the zero line, a short almost horizontal stretch interrupts its course. This interruption is marked *b* on the curve, and may be taken to indicate a second onset of activity in the muscle following the first at an interval of about 3 σ. After this interruption the curve descends, forming a sharp downwardly directed summit and then ascends to be again interrupted. There is an irregularity about the curve which inevitably suggests interference between different trains of oscillations.

Fig. 6 is the curve obtained from the same muscle, with the electrodes undisturbed, when the hammer was transferred to the opposite foot—that is to say, it is the heteronymous reflex response corresponding to fig. 5, which is the homonymous response. Here we see, as in fig. 5, an interruption on the descending limb of the first deflection. This occurs considerably before the zero line is reached and forms a distinct second upward deflection, whose summit is separated from the summit of the first deflection by about 3·2 σ. The curve is a long-continued one of complicated form, nine upward deflections at least can be counted in the curve. Measuring from summit to summit of the deflections the rate is about 296 per second, the average time-difference between the summits being about 3·4 σ.

It is interesting to observe that this curve can be very closely imitated by the result obtained from the interference of two trains of damped oscillations of different frequencies—a rapid and a slow series—as shown in diagram fig. 7. In this diagram curve 1 is a tracing of fig. 6 ; curve 2 gives the result obtained by algebraic summation of the two trains of damped oscillations shown in curve 3.

The resemblance in form of curves 1 and 2 is so marked as to suggest that this method of representation may be of use in studying such reflex electrical responses.

We have seen that the responses obtained in reflex muscular activity elicited by a single mechanical stimulus, present different degrees of complication, ranging from a regular series of gradually diminishing deflections, which I have attributed to peripheral rhythm, to forms such as fig. 6, and we have considered that the probable explanation of the increasing complexity is to be found in the occurrence of successive discharges from the spinal centre.

In diagram fig. 8 I have traced five responses of increasing complexity, one below the other, with the summits of the first deflections on a vertical line.

Curve 1 of the diagram is of similar form to figs, 2, 3, and 4 and shows a

Curve 1.

Curve 2.

Curve 3.

5σ
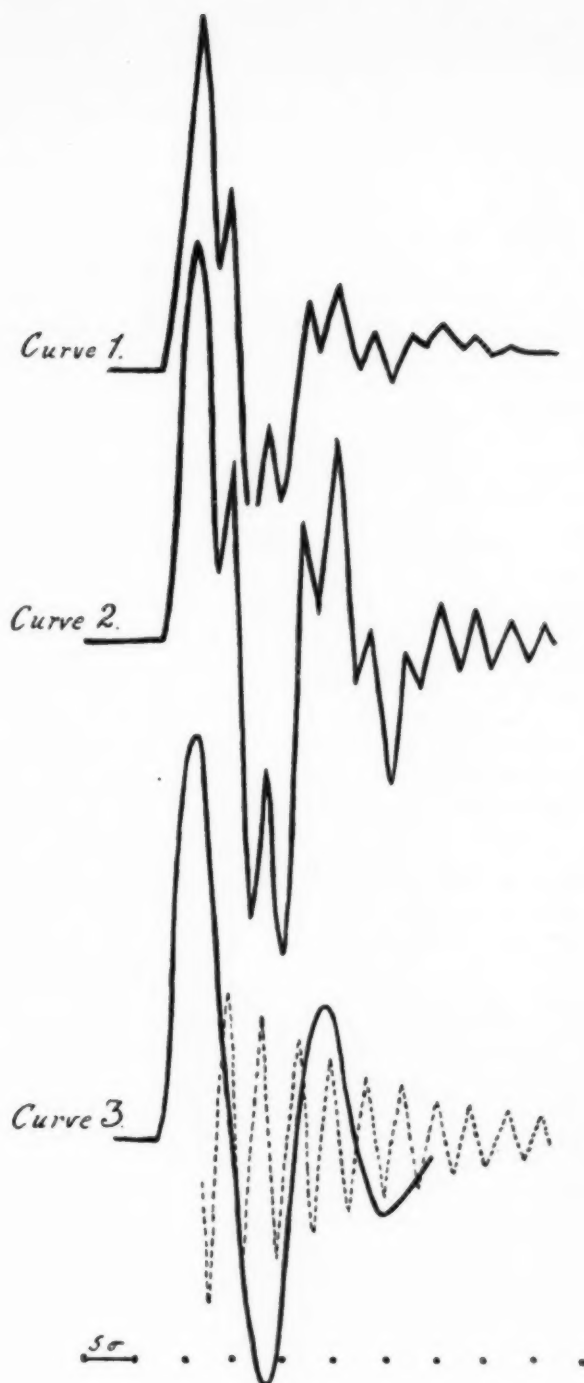
Fig. 7.

series of four oscillations diminishing in amplitude. The record was made at gullet T. of 20·5° C. by a tap on the foot of the same side. The average interval between the summits of the deflection is about 8·4 σ. Curve 2 is the response of the same muscle with the electrodes undisturbed and other conditions the same, and the hammer transferred to the opposite foot. The first deflection in this curve is seen to be higher than that of curve 1, a difference which is commonly found between homonymous and heteronymous responses, but the most striking change is the appearance of an interruption, lettered b on the descending limb of the first deflection, shortly before it reaches the zero line. It will be seen that the sequence of the subsequent oscillations has now become changed from what it is in curve 1.

To make this more evident, I have superposed curve 2 on curve 1 as a dotted line, and there can be little doubt, when the two curves are compared in this way, that the interruption b indicates the onset of a new series of oscillations which interfere with those belonging to the series initiated by a.

Curve 3 is another homonymous reflex from the same frog at gullet T. 18·5° C. It is of the same type as that given in fig. 5. It shows the first deflection and the interruption b as in curve 2, and in addition there is evident another interruption occurring later and marked c.

Curve 4 is the response given in fig. 6, and is a heteronymous response at gullet T. of 22·6° C. from the same frog which yielded the first three curves of the diagram. We see that it shows upward summits at b and c. The summit b follows the summit of the first deflection at an interval of about 3·2 σ.

Curve 5 is a heteronymous response from another frog at gullet T. 20° C., and shows at least four upwardly directed summits, lettered a, b, c, and d. The average interval between them is about 3·8 σ.

The evidence, I think, points to the fact that in curve 5 we are observing the effect of four successive impulses received by the effector organ from the motor neurones of the spinal centre, while in curve 1 a single impulse has been received from the centre and the peripheral response to this single impulse is oscillatory. The intermediate curves, 2, 3, and 4, all owe their form to the reception of successive impulses from the centre.

This conclusion gives rise to a question of some interest. The type of response shown in curve 3, which I consider indicates successive impulses from the centre, is also sometimes obtained in the isolated nerve-muscle preparation stimulated by a single induction shock applied to the motor nerve. The more usual response is the regular oscillatory form which I have given in fig. 1, but there is no doubt that the type of curve 3 also occurs. How are we to reconcile this fact with the assumption that more than one impulse is necessary for the production of curve 3 ? I think

Curve 1.

Curve 2.

Curve 3.

Curve 4

Curve 5
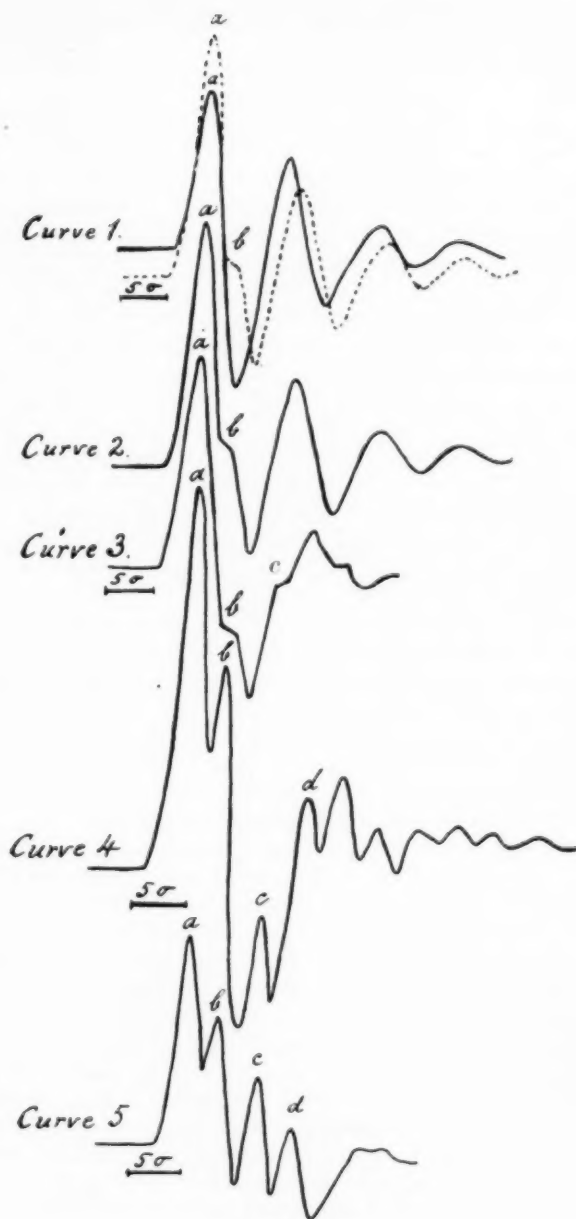
FIG. 8.

the explanation is to be found along the lines indicated by Forbes and Gregg (13).

These authors have found that when a motor nerve is stimulated with a strong induction shock, the record of the action-current often shows a second excursion of the galvanometer string, which suggests as its cause that two impulses have been produced in the nerve by the stimulus, and they put forward the explanation that a strong induction shock is capable of causing a local excitatory process which lasts long enough to initiate two or even three impulses in the nerves. Forbes and Gregg quote Garten's observations (14) and his interpretation of them in support of their view, and consider that if the ionic disturbance set up by the induction shock be great enough, and the shock persist long enough with an intensity sufficient to maintain adequately the ionic concentration, the refractory period may end in time for a second disturbance to be initiated.

If we adopt this explanation, which seems to be a very probable one, then we need not be surprised to find that occasionally responses to single induction shocks applied to the motor nerve are of the form of curve 3. Their occurrence would merely depend upon the use of a sufficiently strong induction shock, and need not lead us to question the assumption we have made that this form of response requires more than one impulse.

The next question that arises is why the spinal centres should usually, although not always, send out several impulses to the muscle when the stimulus is a light tap on the foot. I have assumed that this light blow is of the nature of a single stimulus and may be compared to a single induction shock of moderate strength applied to an afferent nerve. The fact that frequently the response from the muscle is a twitch, if we adopt the explanation here advanced for the regularly rhythmic variations, strengthens this assumption. If that is so, then we must conclude that a single afferent impulse can lead to several impulses being sent out by the motor centre to the effector organ. There is some support in the literature for this view. Thus Beritoff (11) concludes from his experiments that the spinal centres possess the capacity of responding to a brief stimulus with a series of excitation waves. Forbes and Gregg (15) find that records from the mammalian tibialis anticus when acting reflexly in response to a single shock applied to an afferent nerve show considerable variety in the shapes of the curves. While some of them seem to indicate simple twitches, others are more complicated, and some distinctly dicrotic. From the motor nerve also the electrical responses are sometimes distinctly dicrotic. While these authors are inclined to attribute the dicrotism to scattering in time of the discharge, their observations are not inconsistent with the view that the motor neurones have discharged more than once.

If we adopt this assumption we would see in curve 5 of fig. 8 evidence

of an inherent rhythm of discharge of the spinal centres under the conditions of experiment, *i.e.* about 265 per sec. at 20° C. In connection with this, however, the results of Adrian and Olmsted (16) on reflex refractory phase must be kept in view.

Another possibility which must be taken into account is that several paths of different complexity have been traversed by the nervous impulse in its passage through the spinal centres and that the motor neurones receive stimuli through these paths successively, so that the discharges giving rise to the successive summits of curve 5 would be separated from each other by a time-interval corresponding to the delay at a synapse or set of synapses. In a previous communication (2) I have suggested that in the decerebrate frog a double character in the response may be due to the passage of the nerve impulses which play upon the motor neurones through two paths in the centres, one of which contains more synapses than the other, so that the impulse traversing it reaches the motor neurones later. Forbes (17) also has suggested that repeated action of the motor neurones may be due to conduction through an extensive series of branching paths in which the delays will be of different magnitude according to the number of synapses involved. The time-interval here found in curve 5, viz. 3·8 σ, corresponds to what I have concluded to be the delay at a synapse or set of synapses (probably a linked pair) in the frog (2), and this lends probability to this interpretation.

Some electrical variations have been recorded in the present research, which, while showing rhythmic oscillations, are not of a "diphasic" character—that is to say, the curve oscillates above the zero line without crossing it. It is reasonable to suppose that where the curve crosses the zero line, as in those figured in this paper, its form is due to two components commencing almost synchronously, which sum to give the recorded curve, one component oscillating above the zero line, the other below the zero line. From the form of the variations obtained during the investigation I would suggest that the regularly rhythmic responses are built up as shown in diagram fig. 9. The two components are represented as commencing about the same time, but one rises more steeply at its commencement than the other.

It should be pointed out in connection with this attempt to analyse the electrical responses of muscle that Hermann's conception of the causation of the diphasic variation in muscle does not hold the field unchallenged. Doubt has been thrown upon it by Tschirjew (18) and by Henriques and Lindhard (12).

I do not propose at this time to discuss the general question of the causation of the diphasic variation. My concern has rather been with the question of how far successive central impulses are involved in the peripheral response in the reflexes studied and how far they explain the form assumed

by the electrical variation, but in the course of the work it has become
evident that the twitch response in the effector organ, when the conditions

Fig. 9.

are quite normal, is probably of an oscillatory character, and it would seem
that a recognition of this will make it necessary for us to revise to some extent

the current views, based on Hermann's work, of the processes which underlie the electrical changes in active muscle.

SUMMARY.

The action-current of the gastrocnemius of the spinal frog has been recorded in response to a single mechanical stimulus—a light hammer tap—applied to the foot of the same or of the opposite side.

It is found that the electrical variation indicates in some cases that a twitch of the muscle has occurred, due to a single impulse from the spinal centre, and in other cases gives evidence that more than one impulse has reached the muscle and that the form of the curve is then due to interference.

It is probable that the response of the muscle, when the conditions are quite normal, to a single impulse reaching it through the motor nerve is usually oscillatory in character.

The regularly rhythmic or oscillatory form of response is attributed to a single discharge from the motor neurones.

Records are figured in which there is evidence of successive discharges from the spinal centres, separated by time-intervals of from 3 to 4 σ (thousandths of a second).

The suggestion is made that the regularly rhythmic variation may be analysed into two components commencing almost synchronously, one oscillating above the zero line, the other below.

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DESCRIPTION OF FIGURES.

Fig. 1. Electrical response of gastrocnemius of isolated nerve-muscle preparation to break induction shock applied to sciatic nerve. Leads from nervous equator of muscle and tendon. T., 19° C. Tuning-fork, 200 D.V. per sec.

Fig. 2. Electrical response of gastrocnemius contracting reflexly in response to single mechanical stimulus applied to the foot of the opposite side. T., 19° C. Tuning-fork, 200 D.V. per sec.

Fig. 3. Electrical response of gastrocnemius contracting reflexly in response to single mechanical stimulus applied to the foot of the opposite side. T., 19° C. Tuning-fork, 200 D.V. per sec.

Fig. 4. Electrical response of gastrocnemius contracting reflexly in response to single mechanical stimulus applied to the foot of the opposite side. T., 14° C. Tuning-fork, 200 D.V. per sec.

Fig. 5. Electrical response of gastrocnemius contracting reflexly in response to single mechanical stimulus applied to the foot of the same side. T., 22·6° C. Tuning-fork, 200 D.V. per sec.

Fig. 6. Electrical response of gastrocnemius contracting reflexly in response to single mechanical stimulus applied to the foot of the opposite side. T., 22·6° C. Tuning-fork, 200 D.V. per sec.

Fig. 7. Diagram showing :—*Curve* 1 : Electrical reflex response of gastrocnemius to heteronymous stimulation. T., 22·6° C. *Curve* 2 : Algebraic summation of two interfering trains of damped oscillations for comparison with curve 1. *Curve* 3 : Two trains of damped oscillations of different frequency, whose summation gives curve 2. Time-marker, 200 per sec.

Fig. 8. Diagram showing :—*Curve* 1 (continuous line): Electrical reflex response of gastrocnemius to homonymous stimulation. T., 20·5° C. (The corresponding heteronymous response—curve 2—is superposed as a dotted line.) *Curve* 2 : Electrical reflex response of gastrocnemius to heteronymous stimulation showing the appearance of an interruption, lettered *b*, not present in curve 1. *Curve* 3 : Electrical reflex response of gastrocnemius to homonymous stimulation. T., 18·5° C. *Curve* 4 : Electrical reflex response of gastrocnemius to heteronymous stimulation. T., 22·6° C. *Curve* 5 : Electrical reflex response of gastrocnemius to heteronymous stimulation. T., 20° C. The diagram illustrates the complication of the responses brought about by successive impulses from the spinal centre.

Fig. 9. Diagram showing suggested analysis of oscillatory curve. The continuous line gives an electrical reflex response of the gastrocnemius to homonymous stimulation. T., 20·5° C. The interrupted lines represent the two suggested components, commencing about the same time, but one rising more steeply at its commencement than the other. The one component oscillates above the zero line, the other below the zero line.
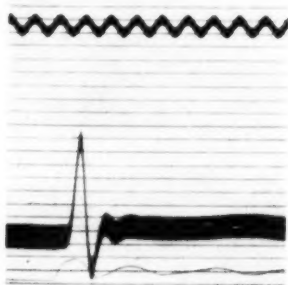
Plate II.

Fig. 1.

Fig. 2.
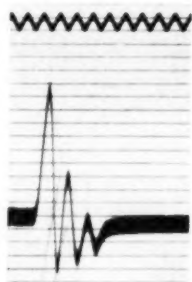
Fig. 3.
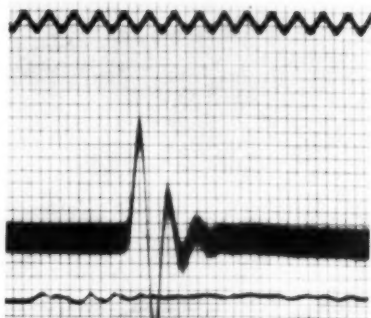
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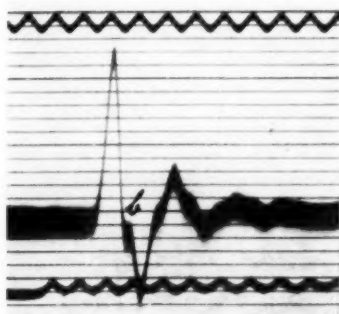
Fig. 5.
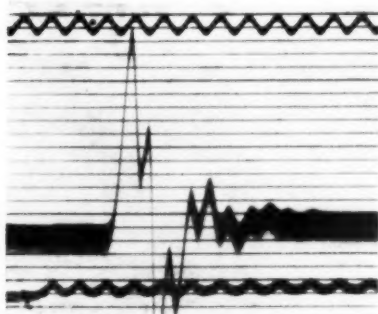
Fig 6.

THE VOLCANIC ROCKS SOUTH OF ZUURBERG.

By S. H. HAUGHTON, D.Sc., and A. W. ROGERS, Sc.D., F.R.S.

(With Plate III and two Text-figures.)

Sixteen years ago the senior author described before the South African Philosophical Society some volcanic rocks occupying an unusual position along a fault for twelve miles on the southern flank of the Zuurberg range in Alexandria and Uitenhage.* Further information, especially concerning their petrographical characters, was published by the Geological Commission,† and the conclusions reached were that the volcanic rocks were of post-Uitenhage age and "rose along the line of faulting during or after the production of the fault." It was added that "this explanation does not account for certain facts, the presence of a band of pipe-amygdaloid in the Mimosa valley, where the 'pipes' are arranged perpendicularly to a plane which dips about 20° towards S.10°W., and the existence of a band of scoriaceous lava parallel to the pipe rock."‡

During the past two years the junior author has made a geological survey of the whole of the area occupied by the Uitenhage beds south of Zuurberg and has found in several places conclusive evidence of the pre-Uitenhage age of the volcanic rocks, which are unconformably overlain by Uitenhage beds. There is no longer reason to think that the volcanic rocks rose along a fault, for it is evident that their association with faults is due to their being the lowest horizon exposed on the downthrow sides of the faults at the several places where they appear at the surface.

The recent work has proved that the volcanic rocks extend through an area about 100 miles in length from east to west along the northern boundary fault of the Cretaceous beds, and that they are continued southwards round the western end of the Cretaceous area, following it again towards the east on its southern side for 23 miles, where there probably is a fault separating the Cretaceous and volcanic rocks from the Cape formation of the Winterhoek region.

* A. W. Rogers, Trans. S.A. Phil. Soc., xvi, pp. 189–198 (1905).

† Ann. Rep. Geol. Com. for 1905, pp. 12 and 34–42.   ‡ *Ibid.*, p. 41.

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Fig. 1.

Sand.

Tertiary and later Marine beds.

Cretaceous (Uitenhage) beds.

Volcanic and associated beds.

Ecca.

Dwyka.

Witteberg.

Bokkeveld.

Table Mountain sandstone.

Pre-Cape rocks.
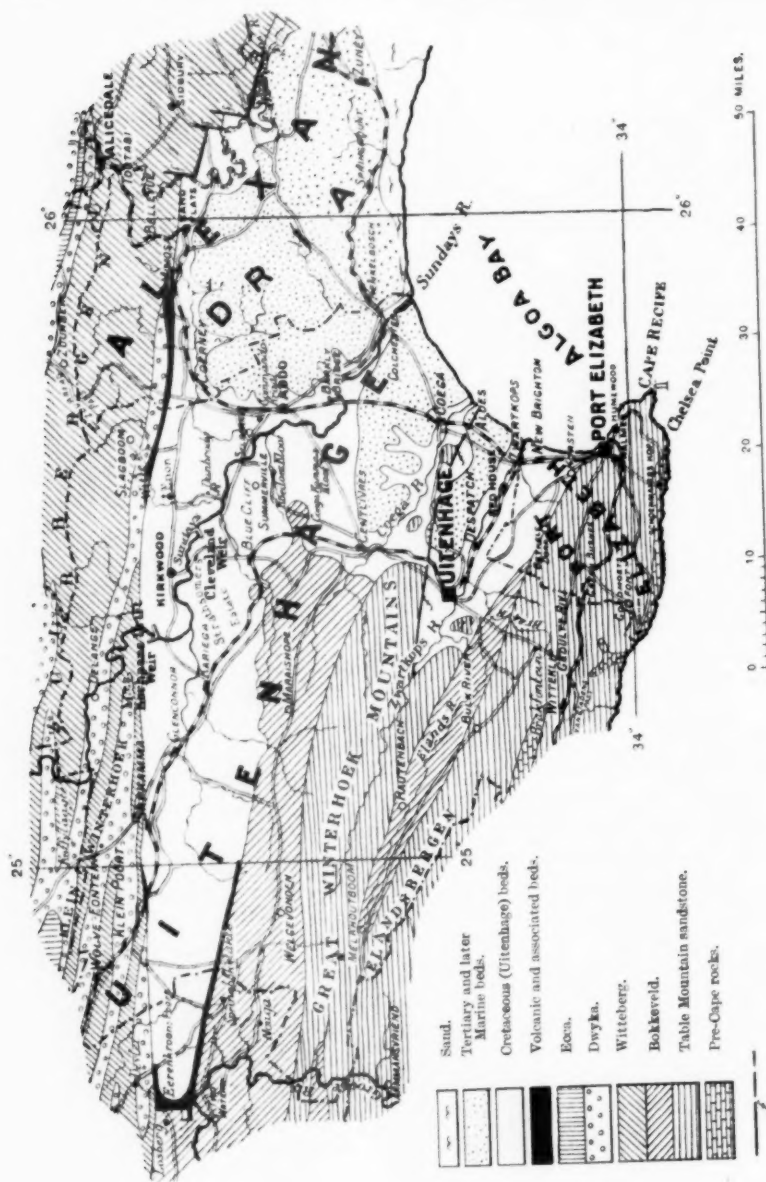
The new evidence proves the volcanic rocks to be part of a formation lying unconformably below the Uitenhage beds, and the two groups to have been faulted down against rocks belonging to the Cape and Karroo systems. It also suggests that the volcanic rocks and the sediments immediately underlying them belong to the Stormberg series of the Karroo system, but up to the present time that has not been proved.

The authors have visited together most of the newly discovered exposures west of Bushmans River; those east of that river have been seen by the junior author alone.

The first proof of the pre-Uitenhage age of the volcanic rocks was obtained in the recently made irrigation canal on Landrosts Vee Plaats, where a weathered pebble of basalt with amygdales of heulandite and several pebbles of tuff similar to well-known types of tuff in the volcanic belt under Zuurberg were found in a conglomerate containing calcified wood and forming part of the Uitenhage beds. The basalt pebble is too weathered for microscopic examination, but in its general appearance and the presence of heulandite it exactly resembles some of the lavas which crop out to the north. Six thin slices cut from the tuff pebbles show that these have the same characters as the tuffs which crop out in the volcanic belt to the north; they are made chiefly of angular grains of quartz and felspar set in a matrix which is too fine-grained to allow the determination of individual particles; in the green pebbles there is an abundance of a green mineral, presumably chlorite, in the matrix; fragments of devitrified basaltic lava deeply stained red by oxides of iron, as is usually the case in outcrops of the lava, occur in the red tuffs.*

The country occupied by the volcanic rocks mapped in 1905 was again examined and an important correction of the conclusions reached was made on Slagboom, where the base of the Uitenhage beds makes a curved outcrop, projecting northwards on the ridges between the kloofs running south towards the area made of Uitenhage beds. The ground being well covered with soil and bush, outcrops are not often found at the desired spots, even in the stream beds, but the fact that the Uitenhage beds lie on the volcanic rocks is obvious from the course taken by the outcrop of the basal conglomerate of the Uitenhage beds, which is illustrated by the view in Plate III. Searching the ground on the kloof side below an outcrop of the conglomerate reveals large fragments of the volcanic rocks in positions indicating with certainty their passage southwards under the Uitenhage beds on Slagboom, and a similar relationship is more clearly seen on Enon.

In a kloof on the eastern side of Slagboom the rock south of the Dwyka tillite and nearest it is a breccia-gravel, apparently the result of the weather-

* Descriptions of the tuffs on pp. 36–39 of Ann. Rep. Geol. Com. for 1905 can be applied exactly to these pebbles.

ing in place of a breccia ; this rock may lie between the tillite and the basalt, and it may be comparable to the breccia recorded in the Coerney River in 1905.* The total thickness of the volcanic rocks at this place is from 470 to 500 feet, and they dip south at 20° ; basalt is at the base, above the breccia mentioned above, then come bedded sandstones or tuffs, spotted and partly silicified, a breccia with angular pieces of quartzite and finally a considerable thickness of basalt ; Enon conglomerate caps the hill at the south end of the section.

The White River cuts the volcanic rocks on Slagboom, but a very small area of the volcanics remains on the right bank ; the volcanic belt does not make such a pronounced bend as is shown on the maps drawn in 1905, but it continues in a general W.8°N. direction towards Enon. The White River is a meandering stream with a general westerly direction as far as a point north of the Mission Station, where it turns through a right angle to join Sundays River. Deep, narrow, heavily bushed kloofs open into it from the north on Enon : its southern bank is formed of red Enon conglomerate out of which the river has cut prominent cliffs. The conglomerate forms rounded, bush-clad hills a few hundred feet high. About 2½ miles to the east of the big bend in the White River there is a large cave in the conglomerate cliff on the left bank at a horseshoe bend in the river. The kopje on the south side of the river immediately to the east of the cave is of Enon conglomerate, but near its base, just south of a small patch of mealies and west of a footpath leading over the hills towards Coerney Station, there is an outcrop of amygdaloidal basalt traceable for a few yards only. Between the basalt and the river nothing is seen but gravel and alluvium.

On the opposite side of the river there are two kopjes ; up the eastern side of the western kopje there is a footpath leading up over rotten basalt, and the slopes on either side of it carry a number of pink tuff boulders and rounded quartzite boulders lying on a stiff black soil. Within less than 100 yards of the top, however, the basalt disappears and no more tuff boulders are seen ; quartzite boulders and pebbles are met with right to the top of the kopje, many of them having the crushed character of typical Enon boulders. North of the cattle-path leading along the side of the kopje no basalt is seen ; tuffs occur for a hundred yards or so and then suddenly give place to tillite.

In the next kloof, a few hundred yards to the west, the width of the volcanic group is nearly half a mile ; basalts are only exposed occasionally, but they are seen in place within 25 yards of the most northerly outcrop of Enon conglomerate. Tuffs and tuff-breccias are the commonest type of rock seen here. In one breccia a quartzite pebble 4 inches in diameter

* Trans. S.A. Phil. Soc., xvi, p. 194.

was obtained. The relation between the tillite and volcanic rocks cannot be seen here.

Passing over a nek into the next kloof to the west, the hill between the nek and the river is seen to be made of Enon conglomerate, while tuff and basalt occur on the nek and the southern face of the hill to the north. Tuff and breccia boulders are numerous in the wash-out running westwards from the nek, and there are large blocks of a peculiar conglomerate which seems to occur in place about a third of the way down. This conglomerate contains pebbles up to 4 inches in diameter set in a matrix of volcanic material and grit ; some of the pebbles are crushed after the manner of pebbles in the Enon conglomerate, and there are agate pebbles amongst them. Three thin sections from this conglomerate show that it is made of pieces of red quartz-felspar sandy tuff, like the sandy tuffs from the volcanic beds, quartzites, agates, green micaceous slaty rock, and deeply red-stained basalt adhering to agate. We think that this conglomerate is at the base of the Uitenhage series and belongs to it.

Ascending the kloof which enters the White River at the bend north of the Mission Station, one meets with tillite soon after leaving the river ; careful search failed to reveal any volcanic rocks between the tillite and the alluvium, and Enon conglomerate crops out immediately south of the river.

The evidence near Enon points to the conclusion that a fault separates the tillite from the volcanic rocks, and that the latter dip south under the Enon conglomerate, which overlies them unconformably, having been deposited upon a very uneven surface of basalt and sandy tuff. This conclusion is in accordance with the discovery of basalt and tuff pebbles in the conglomerates much higher in the Uitenhage series on Landrosts Vee Plaats and Paltjes Kraal.

Westwards, the next outcrops of volcanic rocks were found on Matjes-goedfontein, 35 miles west of the outcrops on Enon. Amygdaloidal basalt is seen in a donga just north of Mr. Snyman's house for a distance of 30 yards from north to south. Fragments of basalt in the soil prove that the rock extends as far as the eastern boundary of the farm, but no further outcrops were seen. The whole width of the volcanic band is here perhaps 100 yards ; Witteberg quartzites lie immediately to the north of it, and Enon conglomerates to the south.

Fifteen miles to the west of the outcrops on Matjesgoedfontein the volcanic rocks appear at the surface on De Vlei in the Steytlerville Division. The outcrops appear on the road leading to Tyger Kop and Springbok Vlakte. Three hundred yards south of the river the road is on basalt, the intervening stretch being covered with sandy calcareous tufa and gravel. The basalt is much weathered and almost covered by soil at first, but higher up

the road almost continuous exposures are seen. The succession is as follows, the measurements being corrected for the diagonal course of the road across the volcanic band but not for dip, which appears to be high and to the south :—

Pink and green basalt, with small amygdales or none . 350 feet
Amygdaloidal basalt . . . . . . 28 ,,
Pink sandy tuff . . . . 6 ,,
Amygdaloidal basalt . . . . . . 4 ,,
Fine-grained basalt, gradually becoming amygdaloidal . 140 ,,
Amygdaloidal basalt . . . . . . 2 ,,
Total width seen . . . . . 526 ,,

In and near the bed of the stream just to the west of the road there are good exposures of the volcanic rocks, into which a bore-hole has been sunk. Some 60 feet of pink and pale buff tuffs, sandstone, and breccia are followed by basalts, the breccia lying between the sediments and basalt. In the bed of the stream west of the bore-hole the basalt is well exposed. Pieces of finely laminated sandstone lie about, but an outcrop of this rock was not seen. Some of the pink sandstone has broken layers of dark mud-stone-like material, looking like clay-pellets. Outcrops of green tuff also occur in the stream bed. The breccia contains fragments of fine-grained quartzite and chalcedony.

To the east of the road the volcanics are only seen in one small exposure near the drift ; here pink tuff lies on the south side of highly amygdaloidal basalt, and there is an apparent dip of the whole to the south.

Immediately to the north of the volcanic rocks on De Vlei there is Dwyka tillite, but the lower shales probably come in near the Dorschfontein boundary, which passes over the abruptly truncated end of a ridge made of Witteberg beds. To the south of the volcanics nothing is seen but gravel and red loamy earth, the gravel becoming coarser as one ascends the higher ground of a peneplain which lies at about 1500 feet above sea-level.

To the west of the road to Tyger Kop there is an outcrop of the tuffs on the bush-covered ground near the Dorschfontein boundary, and the rocks are probably continuous with the outcrops on Eerenkroons Poort, where particularly good exposures occur. On this farm bush-covered hills of Enon conglomerate are bounded on the north, west, and south by basalts and tuffs, which form low ground, and are in places only visible in the gullies, as in those draining into Brakpoort. Close examination shows that the upper surface of the volcanic group is uneven. In the easternmost gully there is an exposure of pink and blue marly and clayey beds lying below the nearest basalt outcrop and apparently dipping under the basalt.

REFERENCE.

Alluvium.

Conglomerate Enon. Cretaceous.

Gritty sandstone.

Tuff conglomerate.

Basalts. Volcanics

Tuffs.

Witteberg Beds.

Bokkeveld Beds.
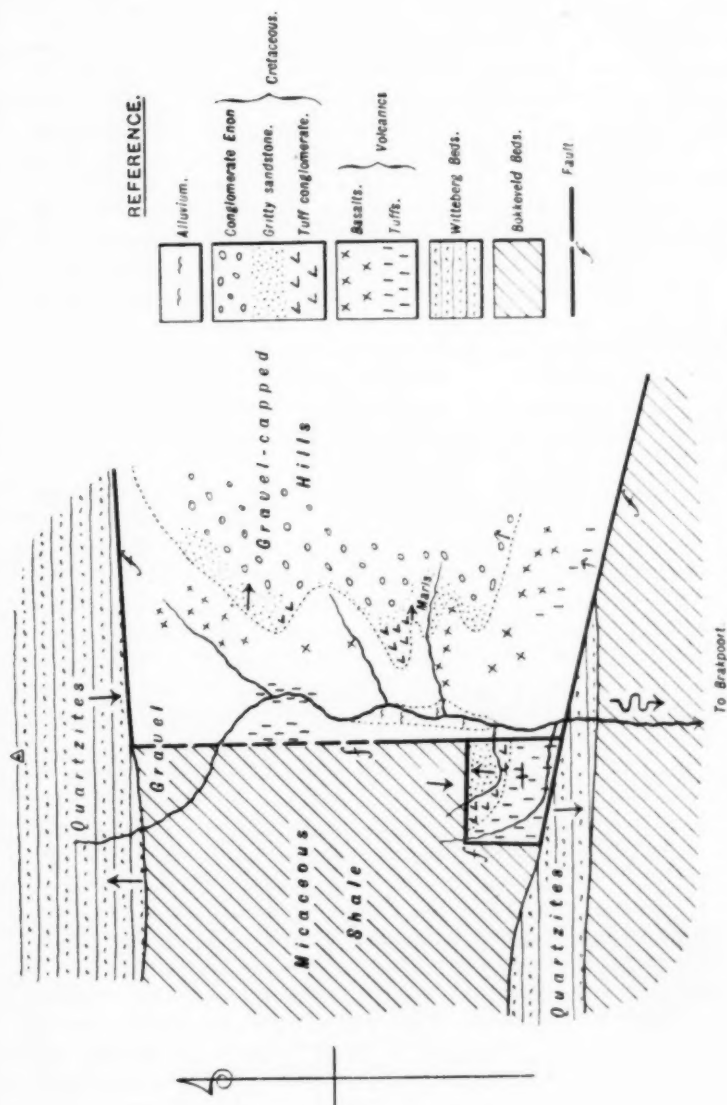
Fault

Fig. 2.—Sketch Plan of outcrops on Eerenkrooms Poort.

Scale. 1 inch = 1400 yards.

The western boundary of the volcanic group is a north-south fault, the volcanics abutting against Bokkeveld beds dipping at 50° to the south-east except at the south end, where a roughly rectangular area is faulted down beyond the main mass of the volcanic and Uitenhage beds. The southern half of this rectangular area is made of pink tuffs dipping vertically or at a very high angle to the south, and within five feet of the fault separating them from the Witteberg beds they contain angular and subangular pieces of quartzite. The tuffs are overlain by gritty sandstones containing pebbles and debris from the volcanic beds. To the east and north the basal Cretaceous beds lie on an uneven surface of basalt and contain much debris from that rock. In places marl lies directly on the basalt. In the northern part of the tuff outcrop, west of the Cretaceous beds, there are silicified bands interbedded with the tuffs.

The volcanic rocks can be traced eastwards for 23 miles from Eerenkroons Poort through Eerenkroons Berg, Drie Kuilen, Tyger Kop, Beyers Vley, Springbok Vlakte, and Gorie Laagte, to Rhenoster Hoek, where they finally disappear. Throughout the whole of this strip the outcrop is never more than half a mile wide, sometimes less than half of that; wherever dip can be made out (except at the extreme western end as noted above), the beds dip at a low angle under the Cretaceous beds to the north. On Rhenoster Hoek they are cut off by a probable fault which runs in a north-north-easterly direction towards Sapkamma, and brings the variegated marls directly east of the Enon conglomerate. The most interesting exposures along this stretch of country are in a gully on Drie Kuilen. Generally the Bokkeveld beds to the south of the volcanic rocks are separated from them by several hundred yards of gravel-covered ground on which no outcrops can be seen, but in the gully on Drie Kuilen a succession of sediments is seen dipping at about 12° beneath the basalts and tuff. The lowest beds seen north of the Bokkeveld shales are breccias and conglomerates of angular pieces of quartzite and sandstone; these fragments are but slightly rounded and some of them are cracked after the manner of the boulders in the Enon conglomerate. Above these come red and blue clays, hardened red and blue marls containing indeterminable fragments of bone, soft red marls, and hardened white marl with reddish spots; then follow white sandstones, pink tuffs and tuff-breccia, and basalts. The sedimentary rocks below the volcanics are about 200 feet thick and the volcanics 420 feet. Immediately north of the volcanics is an outcrop of thin reddish-brown sandstone, reddish pebble-beds, and gritty sandstone with clay-pellets, the basal beds of the Cretaceous. The pebble beds contain numerous pieces of pink tuff in addition to quartzite, sandstone, and micaceous shale; the whole being very similar to the basal Cretaceous beds lying on the basalt and tuff on Eerenkroons Poort.

On Beyers Vley Outspan we exposed the base of the Uitenhage beds by digging into the left bank of the stream. Red and pink marls lie on a slightly uneven surface of weathered basalt which is coated with a layer of gritty material from a quarter to half an inch thick, coloured green by chlorite. There are no coarse fragments or pebbles in the marls at this place, and an absence or paucity of large fragments at the base of the Uitenhage beds is the rule along the southern edge of this area of those beds. The contact was exposed for about 18 inches only ; it dips towards N.15°E. at an angle of 45°, and the rather faint traces of bedding in the marls dip at 26° in the same direction. There is no hardening of the marls near the contact, and there is no evidence of movement along it, so it is probably an unconformity, not a fault or a surface of intrusion.

On Springbok Vlakte No. 2 there is a small exposure of marls in a pit lying between the volcanic rocks on the north and the Bokkeveld beds to the south.

Eastwards of Rhenoster Hoek no exposures of the volcanic rocks were found on the south side of the Cretaceous beds, and the junction of the latter with the Bokkeveld beds seems to be an unconformity.

The junior author re-examined the exposures on Thornleigh. About 1½ mile N. of Walton's house is a new farmhouse (Nosworthy's) standing on a hill of basalt. From this house a footpath leads west and then north to Nieuwe Poste, passing round the head of a short kloof running east into the main kloof. At the head of this kloof basalt gives place to pink sandy tuff and this, after a few yards, to tuff-breccias which extend to the Witteberg quartzites. In the main kloof the basalt-tuff series is followed to the north by a conglomerate of crushed and uncrushed slightly rounded pebbles set in a red and blue clayey matrix, somewhat similar to the conglomerate below the volcanics on Drie Kuilen. The only exposure is in a small kranz on the west side of the kloof at the foot of a wooded hill on whose slopes basalt boulders occur. This occurrence is about 200 yards south of the well sunk in Dwyka Tillite, mentioned in the 1905 paper, and which is now just to the south of the Unamore-Northwood fence. On the hills both to the east and west of this well basalts and tuffs outcrop. The conclusion is reached that the tongue of tillite in this valley has been let down on the south side of the main fault, and that it is unconformably overlain by a pre-volcanic conglomerate which underlies the basalts and tuffs.

To the east of the country in which the volcanic rocks were seen in 1905 the only fresh indication of their presence west of Bushmans River was the occurrence of fragments of tuff in the soil near the entrance to the Waggwa gorge from the south. East of Bushmans River, however, outcrops of tuff were found on Solomon's Temple, Woodbury, and the farm Bushmans River.

Proceeding eastwards from the Bushmans River the first exposure of the volcanics is seen in the N.E. corner of Brakfontein, where a well was sunk through 30 feet of pink sandy tuff at a point about 200 yards south of the faulted southern face of the steeply dipping Witteberg quartzites. From the well the pink and light-coloured sandy rock can be traced for nearly three miles in an E.S.E. direction through the northern corner of Bushmans River Outspan and Solomon's Temple, where, north of the Sidbury road, it disappears beneath the Tertiary limestone. No dip is seen, and the greatest width of the outcrop is less than 100 yards. To the south of this occurrence are Enon conglomerates with abundant fossil wood, dipping to the south. On Solomon's Temple, at the eastern end of the belt, the topmost band below the wood-bearing conglomerates is a tuff-conglomerate containing pebbles of quartzite.

Another belt of sandy tuffs occurs on the farms Woodbury and Bushmans River. This is probably slightly more than 3 miles long, although its extreme western end has not been seen on account of the gravel and soil cover. The strip lies between the Witteberg quartzites to the north and the Cretaceous beds to the south and is well exposed at several places.

(*a*) Just south of the main road at the east end of Woodbury a road-metal quarry shows a few feet of red and blue finely-bedded marly material overlain by grey and light-coloured sandy tuffs shot with red—some very fine-grained, others pisolitic; these dip at about 15° to the south.

(*b*) A few yards to the east is a cliff of tuffs; and at the cliff at the bend of the river the tuff-Witteberg junction can be seen along a little footpath just below the top of the cliff. Here highly-dipping reddish sandy tuffs rest against brecciated quartzites, the fault-plane being almost vertical.

(*c*) On the right-hand side of the Bushmans River further to the east outcrops of tuff on the slope underlie Cretaceous conglomerates, the relations between the two rocks being well seen in a little tributary valley. The basal bed of the conglomerates is a tuff-conglomerate with quartzite pebbles.

Detailed mapping in this area shows that between Sandflats and Rokeby Park the front face of the Witteberg quartzite is brought progressively southward by a series of three step-faults which cause discontinuity in the outcrops of the Witteberg and volcanic rocks. The non-occurrence of tuffs in the space between two of these faults just north of Stilgenoeg is presumably due to the greater overlap of the Cretaceous beds, for here marls rest against the quartzites and shales.

An interesting feature of this area is the absence of basalts.

PETROGRAPHICAL CHARACTERS.

The characters of the lavas and tuffs between Duncairn and Enon were described in 1905,* and no fresh types of volcanic rocks have been met with in the recently discovered outcrops.   It was then stated that the lava did not resemble closely any known rocks from the Cape, but that it was more like some of the Drakensberg lavas than any others.   Since 1905 a considerable amount of information has been published about the late Karroo lavas in the Stormberg, Lebombo, the Bushveld, and Rhodesia, but no analcime basalts have been noted in those regions.   Excepting this point of difference, however, which applies at least to lavas at Mimosa and De Vlei, there is a closer resemblance to the late Karroo basalts than was recognised in 1905.

Lavas from De Vlei, Springbok Vlakte, and Beyers Vley have been examined in thin section.   A rock from the lowest exposed lava on the road across the volcanic belt on De Vlei (S.H. 479) is an olivine-basalt containing analcime.   The matrix is a mixture of very weakly birefringent, brownish, and colourless substances, often in radiating bunches, titaniferous magnetite and rusty oxides of iron ; there is no glass left ; labradorite is very abundant in small and rather large crystals, the larger ones being zoned ; the texture is subophitic, the larger augites partly enclosing the felspars ; olivine is represented by serpentine.   The amygdales are of analcime and a chlorite. An analysis of this rock by Mr. H. G. Weall gave the following results :—

	I.	II.
Silica .	50·75	50·42
Titania	1·15	1·18
Alumina	13·8	13·32
Ferric oxide	4·65	5·15
Ferrous oxide	6·2	8·52
Magnesia	7·1	5·89
Lime .	8·9	10·70
Soda .	2·85	2·63
Potash	0·85	1·22
Manganous oxide	0·1	—
Phosphoric oxide	0·2	0·20
Water	1·85	0·61
Loss on ignition .	2·35	—
	100·75	99·84

* Ann. Rep. Geol. Com. for 1905, pp. 34–41.

No. I. of the above is the Springbok Vlakte rock, and No. II. is a dolerite described by Dr. J. M'C. Henderson from the Lebombo region.[*]

Mr. Nel reckoned the results on the American system of classification, and found the symbol of the rock to be III.5.3.4, camptonose.

There are as yet too few analyses of late Karroo basalts for comparison ; the one published by Prof. R. B. Young, of a bore-hole core near kilo. 62 on the Goba railway, is probably also of a Karroo basalt, and it is a more basic rock than ours. There is more similarity with a dolerite from the Lebombo, of which the analysis is quoted above.

A thin slice from the basalt of the fourth band of lava on the road through De Vlei (S. H. 476) is very like that from the lowest band in general appearance, though pseudomorphs after olivine are more abundant and the rock is rather finer in texture ; it also has analcime in the amygdales. In polarised light, however, almost all the felspar is seen to be replaced by an undetermined zeolite with positive sign ; the same zeolite fills steam-holes in association with chlorite.

The fifth band of lava (S.H. 478) has amygdales of calcite and chlorite ; the texture is subophitic ; the larger felspars are zoned, and the pseudomorphs after olivine are few and made of a deep red substance.

A lava without olivine from Springbok Vlakte (S.H. 495) has zoned plagioclase crystals containing large inclusions of augite and the ground mass. The devitrified matrix contains numerous small labradorite crystals and crystals of augite ; the amygdales are of chlorite and an undetermined zeolite. Another slice from Springbok Vlakte (S.H. 496) passes through the contact between lava and sediment, a sandy tuff. The lava has deep red pseudomorphs after olivine, granules of augite and labradorite crystals, which are roughly of two sizes, in a nearly opaque devitrified matrix ; the amygdales are of chlorite and heulandite. The sediment is made of angular grains of quartz and felspar (plagioclase) and augite, many irregularly shaped pieces of lava just like the lava in contact with the sediment, and it has cavities filled with heulandite, another zeolite, and chalcedony. There are pieces of sediment in the lava. The contact is very intricate, and it can be explained by supposing that the lava flowed over the surface of soft sediment and caught up fragments of it. The exposures on Springbok Vlakte and Beyers Vley support this view. A thin section of the Beyers Vley lava has no olivine or pseudomorphs after it ; it contains amygdales of heulandite and many inclusions of sandy tuff.

The fragmental rocks were all called tuffs in the descriptions written in 1905, although the presence of basalt debris in them was not recognised

[*] " Notes on some Rocks in the Volcanic Series of the Karroo System in the Lebombo Mountains," Trans. Geol. Soc. S. A., xii, 30.

in the field,* on account of their association with the basalts and in conformity with the hypothesis adopted to explain the occurrence of the whole group of rocks. Many of them were subsequently found † to contain angular and rounded pieces of basalt, and the red tuffs are largely made of such fragments. To these latter varieties the name tuff is properly applied, but the pale sediments are as a whole sandstones with little lava in them, and some of the sandstone and breccias are entirely devoid of lava. The green rocks described as being coloured " by the abundance of weakly doubly refracting flakes of a chloritic mineral " ‡ offer an interesting problem. The exact nature of the green mineral is difficult to determine, as it is in very small flakes more or less closely attached to very fine-grained siliceous and perhaps other material. The discovery of one of these rocks on Slagboom containing recognisable silicified fragments of wood and possibly other organisms raises the question whether the green mineral is all chlorite or partly or wholly glauconite. Chemical analysis would decide the question by determination of the potash content of the mineral, for glauconite has from 0·9 to 9·54 per cent. of potash,§ while the chlorites very rarely have any ; but the condition of the mineral renders its preparation for analysis very difficult, and it has not yet been attempted. The optical properties of glauconite are difficult to determine and in several respects are not easily distinguishable from those of some chlorites ; in the material at present available it is practically impossible to isolate the flakes from their matrix, and an attempt to distinguish them from known minerals failed.

The green rock from Slagboom was found on the northern slope of the prominent hill on the western part of the farm and south of the White River ; it is full of irregularly shaped fragments of silicified vegetable tissue and pieces of branching bodies, also made of minutely crystalline silica, reminding one of broken spicules of sponges ; some of these pieces have cores of less transparent material as though they had been tubular. The plant tissues are of at least three distinct kinds, each of which is in irregularly shaped fragments, indicating that they were embedded as woody fragments which were silicified subsequently. The largest fragment is more than half an inch long and is penetrated by veinlets of the doubtful green mineral, which also occurs in the matrix of the rock. This large fragment and several of the others have a very delicate cellular structure, but yet others have a coarser structure, and some were flattened bodies, like

* Trans. S.A. Phil. Soc., xvi, p. 198.
† Ann. Rep. Geol. Com. for 1905, p. 36.   ‡ *Ibid.*, p. 38.
§ On pp. 242-243 of Cayeux's " Introduction à l'Étude Pétrographique des Roches Sédimentaire," 1916, the analyses of the " Challenger " material are given as well as many others of recent and ancient glauconites.

leaves, with their outer cells elongated in a direction perpendicular to the surface ; the interior of some of these is partly filled with the matrix of the rock, small grains of quartz and felspar in a very minutely crystalline ground mass. In some of the wood there are undetermined crystals with lower refractive index than the silica of the wood and very low birefringence ; they are usually crowded with minute reddish particles.

A green sandy tuff from Springbok Vlakte (S.H. 493) has the green mineral sparsely scattered through the matrix, but it, or a mineral very like it in optical properties, also fills steam-holes in the abundant fragments of lava.

It is a noteworthy fact that none of these sandy tuffs has been found to contain crystals of labradorite recognisable as having been derived from the basalts. Some of the plagioclase in the rocks may have been derived from the lavas, but as microcline and plagioclase of less basic composition than labradorite are present in similarly shaped grains, one suspects that there was some other source of labradorite than the basalts.

Conclusions.

The evidence obtained up to the present time points to the following conclusions :—

1. The folded belt of rocks belonging to the Cape system and lower part of the Karroo system forms an incomplete "frame" defined by faults on the north, west, and partly on the south, within which there is a sunken area.

2. This sunken area consists of Cretaceous rocks lying unconformably upon an uneven surface of marls, sandstones, sandy tuffs, breccias, and basalts.

3. The post-Ecca, pre-Cretaceous formation, of which narrow strips only are exposed round the margin of the Cretaceous rocks, forms a syncline of post-Uitenhage date and is unaffected by the intense folding and cleavage of the Zuurberg-Great Winterhoek region.

4. The Cretaceous rocks pass unconformably across the volcanic and associated beds on to the Cape formation on the south side of the syncline and east of Rhenoster Hoek.

5. The occurrence of bone in the marls below the basalt on Drie Kuilen, together with the general resemblance of the lavas and sediments to those of late Karroo age, renders the correlation of the whole group with part of the Stormberg series probable.

In the event of the correlation with the Stormberg series being substantiated by future discoveries of fossils, there will be proof of the pre-Stormberg age of the Cape folding, which has long been considered probable

on other grounds, viz. the probable derivation of the boulders in the Molteno conglomerates from the Table Mountain Sandstone, and the avoidance of the folded region by the late Karroo intrusions of dolerite. Although it appears certain that the volcanic rocks formed an extensive sheet stretching beyond the limits of the " frame " in which they are now seen, no dolerite intrusions have yet been found in the folded belt in their neighbourhood. The nearest dolerite intrusions known crop out 30 miles to the north, between Niekerk's Berg and the railway north of Middleton Station.

The structure of the down-faulted area recalls that of the sunken areas of post-Uitenhage age described by Prof. Schwarz in the country to the west.*

* Ann. Rep. Geol. Com. for 1903, pp. 73–137 ; also " Baviaan's Kloof," in " Papers Read at the Joint Meeting of the British and South African Associations," etc., ii, pp. 56–67 (1905).
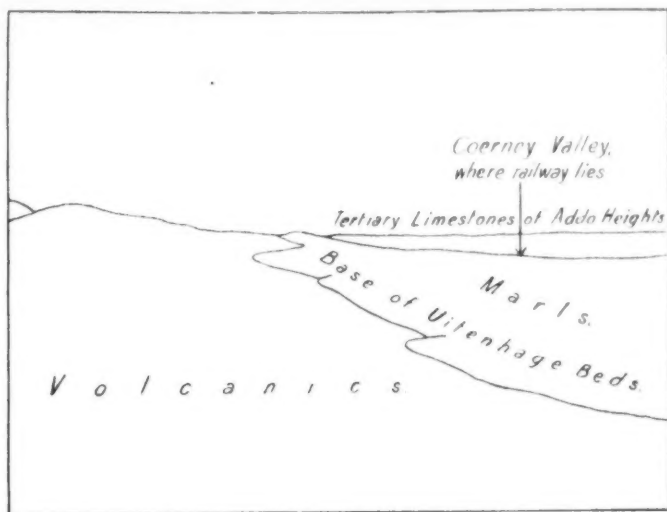
View from hill on Slagboom, looking E. 8° S. along the volcanic belt and the base of the unconformably overlying Uitenhage beds.

PRELIMINARY NOTE ON A POISONOUS ALKALOID FROM THE OVERGROUND PORTIONS OF THE TRANSVAAL YELLOW TULP (*HOMERIA PALLIDA*).

By M. Rindl, Ing.D.

This plant is responsible for heavy losses among stock. It is poisonous both in the dried and fresh condition. Trouble arises from the fresh plant only at certain seasons, the reason being that it makes its new growth of foliage before the rains begin, and at a time, therefore, when green feed is scarce, and stock, in their craving for green feed, eat many plants which they instinctively avoid at other times. As the tulp abounds in grass and lucerne lands, losses due to the occurrence of the dried material in hay are not uncommon. For a description of the botanical characters of the plant, its distribution, poisonous nature, post-mortem appearances, etc., see Bulletin No. 6, 1922, issued by the Department of Agriculture of the Union (Poisonous Plants of South Africa).

The present investigation was carried out at the Imperial Institute, South Kensington, on material which had been collected in the Lichtenburg district, Transvaal, by officers of the Department of Agriculture. Its toxicity was established by feeding tests at the Laboratory for Veterinary Research, Onderstepoort. It was found that a ½ lb. of the dried material was sufficient to kill a sheep, and that an even smaller amount was fatal to cattle.

The balance of the material left from the feeding tests, representing something over 60 lbs., was used for the investigation. Of the dried material, as received, 57·5 per cent. represents stems, leaves, and flowers ; 9·8 per cent. sheaths ; and 32·7 per cent. corms.

As indications of the presence of alkaloids were found in all parts of the plant it was decided to investigate the different parts named above separately.

Preliminary tests established the absence of cyanogenetic glucosides and saponins in the overground parts of the plant. A weighed amount of finely ground material was extracted to exhaustion by hot percolation with a number of solvents, the following results being obtained :—

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Petroleum ether (below 60°)	.	.	2·97 per cent.
Ether .	.	.	.	.	0·46 ,,
Chloroform .	.	.	.	0·55 ,,
Ethyl acetate	.	.	.	1·52 ,,
Alcohol	.	.	.	.	5·11 ,,

Total .   .   .   10·61 per cent.

In no case was the extract distinctly crystalline, and only the alcoholic extract gave alkaloidal reactions. On continued heating the alcoholic extract becomes resinous and insoluble in alcohol. A similar observation with regard to the resinification of the alkaloid had previously been made in connection with a preliminary investigation of the plant carried out at the Imperial Institute.[*]

In view of the sensitive nature of the alkaloid or mixture of alkaloids it appeared desirable to extract the material with alcohol as far as possible in the cold, and to submit the residue subsequently to a short process of hot extraction. The bulk extraction was undertaken by the British Drug House, 13,664 grams of material furnishing 1247 grams of cold extract and 737 grams of hot extract, the extract being weighed in both cases after the solvent had been removed as completely as possible. The cold extract was thick and pasty, the hot one thinly viscous.

For the preparation of a suitable material for physiological tests, 200 grams of cold extract, equivalent to 1377 grams of overground material, were treated in the following way :—

The extract was shaken up once with cold water and five times with warm water, the last portion being practically colourless. As the resin flocculates on shaking with water, it is safe to assume that the water penetrates the extract completely and that everything soluble in water is taken up. On standing, the resin again assumes a tar-like consistency. A small portion of the resin is melted by the warm water and passes through the filter, separating out on cooling. For this reason the hot extracts were collected separately, allowed to cool, and only combined with the solution obtained with cold water after again filtering. The first cold water shaking was of an intense yellow colour, the later aqueous extracts gradually becoming colourless. As the aqueous solution has an acid reaction, complete extraction of the alkaloidal principles can be effected without the addition of any acid.

The combined cold and hot aqueous solutions were precipitated with a slight excess of ordinary lead acetate solution, a bright yellow precipitate being obtained. The acid reaction of the aqueous solution recorded above

[*] Bulletin of the Imperial Institute, vol. xiv, No. 1, Jan.-March 1916, p. 32.

indicates that the alkaloids are present in the plant in the form of salts. The majority, if not all of the acids, are likely to be present in the lead acetate precipitate which was therefore reserved for further investigation. The filtrate was freed from excess of lead by sulphuretted hydrogen, and the dissolved gas was removed by bubbling air through the solution. The acid solution was thereupon extracted once with (a) ether, and (b) chloroform.

The ether extract of the acid liquid (a) gave a thin yellow resin with no indication of crystals. It had a persistent bitter taste, and gave faint precipitates with several, but not with all the alkaloid reagents. The residue, after removal of the solvent, amounted to 0·6895 grams, equivalent to 0·34 per cent. on the weight of the original extract, and corresponding to 0·05 per cent. calculated on the weight of the plant material.

The chloroform extract of the acid liquid (b), on evaporation of the solvent, left a thin yellow resin containing a small quantity of crystals of an indefinite shape. This chloroform extract gives faint alkaloid reactions like those of the ether extract. In both cases these are probably due to a very small amount of alkaloid left as a result of imperfect washing. Taste indefinite; amount, 0·777 grams, corresponding to 0·39 per cent. of the original extract, and to 0·056 per cent. on the weight of the plant material.

The aqueous solution was then rendered slightly *ammoniacal* and shaken up vigorously with *chloroform* (c).

The alkaloidal principle extracted by this method of treatment is obviously very soluble in the solvent used, since a single extraction with a comparatively small volume of solvent suffices for practically complete removal. Emphasis is laid on this point because another alkaloid or a mixture of alkaloids can be extracted from the concentrated aqueous solution by repeated shaking with a large volume of chloroform The chloroform extract (c), after removal of the dissolved ammonia with a small amount of water, and after drying with anhydrous sodium sulphate, was evaporated under diminished pressure, 130–140 mm. and at a temperature of 21°–27° C. The total amount of residue is 0·235 grams, equivalent to 0·017 per cent. on the weight of the plant material. This residue consists of a light yellow, thin, transparent varnish, with a small amount of crystals. The importance of avoiding prolonged heating of the solutions at any stage was confirmed by the fact that the chloroform extract of the ammoniacal solution prepared as described, but using an alcoholic extract of the plant prepared by hot percolation, was a dark brown, opaque, sticky mass.

The light yellow transparent varnish left after removal of the chloroform was prepared for physiological tests by making a cold aqueous solution of such strength that 1 c.c. was equivalent to 275 grams of plant material. It was found that of the 0·235 grams of crude total alkaloid only 0·053 grams went into solution, *i.e.* 23 per cent.

Of the resinous residue only an insignificant amount is soluble in cold dilute hydrochloric acid, but it is appreciably solid in the hot acid, and the solution so obtained gives very marked alkaloid reactions. It seems probable that the proportion of water soluble alkaloid in the plant is greater than the amount given above, and that a considerable proportion of it resinifies during the course of extraction.

The authorities of the Imperial Institute arranged with Professor W. E. Dixon, F.R.S., to undertake the physiological tests with the aqueous solution referred to above, and extracts of the corms and sheaths were submitted to him at the same time.

Professor Dixon reports that the water soluble principle obtained from the chloroformic extract of the overground portions of *Homeria pallida* is a very interesting alkaloid because it exerts a digitalis-like action on the circulation. In large doses it is a cardiac poison. It is not cumulative, so that successive small doses can be administered to animals intravenously without hurting them.

The unpurified alcoholic and aqueous extracts of the sheaths and corms which were also submitted for physiological tests are all similar in their action, and are reported to contain an active substance of the nature of what is usually termed a " cardiac tonic." This substance is very poisonous, and is more closely related in action to squill than to digitalis or strophanthus. Successive small doses administered in the same way as the extract of the overground portions of the plant send the heart into fibrillation and cause sudden death.

Particular interest attaches to these results because the majority of the very large number of substances known to exert an action similar to digitalis are glucosides. So far as the author is aware only one other alkaloid with typical digitalis-like effects is on record—erythrophleine, from the bark of Erythrophloeum Guineense, Sassy Bark. On account of its intensely poisonous properties this bark has long been employed by the natives of Western Africa as an ordeal in their trials for witchcraft and sorcery, as well as for other criminal purposes. It also apparently enters into the composition of the arrow poison of the Pigmies.[*]

The water soluble active principle has a slightly bitter, but not persistent or nauseating taste. It gives precipitates with the usual alkaloid reagents. It is insoluble in benzene, very sparingly soluble in dry ether, readily soluble in alcohol, acetone, ethyl acetate, chloroform, and water.

Attempts to obtain this alkaloid from the overground portions of *Homeria pallida* in a crystalline form and to prepare well-defined derivatives have so far proved unsuccessful.

[*] Power and Salway, "Chemical Examination of the Bark of Erythrophloeum Guineense," American Journal of Pharmacy, August 1912.

The nitrate, chloride, and sulphate were prepared by adding solutions of the acids to the aqueous solution of the alkaloid, and the water was evaporated at ordinary temperature under reduced pressure. The amorphous residue was redissolved, filtered, and evaporated slowly over calcium chloride in a desiccator, but neither salt showed the slightest indication of crystallinity. On passing dry hydrogen chloride into a chloroformic solution of the crude total alkaloid, only a resinous precipitate was obtained.

Picric acid gives a yellow amorphous precipitate both with a neutral aqueous solution and with a solution slightly acidulated with sulphuric acid. An attempt was made to crystallise the picrate from alcohol, but with negative results.

Platinum chloride gives a light yellow precipitate which takes some time to form if the solutions are dilute, and which darkens on keeping. Bromine water gives a flocculent cream coloured precipitate which dissolved almost completely in alcohol. The residue left on evaporating the solvent is amorphous.

The alkaloid displays marked reducing properties. On addition of gold chloride a precipitate is produced, whilst the supernatant liquid assumes the well-known characteristic colours of colloidal gold solutions, turning colourless on standing, as the gold is precipitated. A freshly prepared mixture of potassium ferricyanide and ferric chloride solutions gives a blue precipitate, whilst potassium permanganate, both in acid and alkaline solution, is immediately reduced, in the latter case with the intermediate formation of green manganate solution.

Colour reactions are of doubtful value unless applied to pure substances. A few of these tests were, nevertheless, tried in the present case in the hope of getting results sufficiently typical to be of value in the chemical characterisation of the alkaloid. The colours obtained with concentrated sulphuric acid, with this acid and a trace of nitric acid, with sulphuric acid and potassium dichromate, and with Fröhde's reagent, were, however, all indefinite.

Although the attempts to obtain the alkaloid or a derivative in a form suitable for chemical analysis were abortive, it should be remembered that the amount available was extremely small, and it is quite possible that positive results may be achieved when working with larger quantities.

In spite of the fact that it was not possible to characterise the alkaloid chemically, and although at the present stage it is impossible to assign a definite formula to it, the physiological results are so marked that it would appear to be an alkaloid new to science. As previously stated, erythrophleine appears to be the only alkaloid with a digitalis-like action hitherto recorded. This alkaloid is obviously not identical with erythrophleine, as the latter is insoluble in water, readily soluble in ether, and forms a colourless gold salt,

whereas my alkaloid is soluble in water, insoluble in ether, and reduces gold chloride. With reference to its occurrence, the provisional name Homeridine is suggested for the alkaloid.

The investigation is being continued.

DEPARTMENT OF CHEMISTRY,
GREY UNIVERSITY COLLEGE, BLOEMFONTEIN,
October 1923.

ON MATRICES CONNECTED WITH SYLVESTER'S DIALYTIC ELIMINANT.

By Joseph Kürschák, Budapest.

(Communicated by Sir Thomas Muir, F.R.S.)

We may co-ordinate to every matrix a *representative polynome* depending on x and y in which the coefficient of $x^i y^k$ is equal to the element common to the $(i+1)$th row and the $(k+1)$th column of the matrix.

This being so, let

$$(c_0, c_1, \ldots, c_\mu)_\nu$$

denote the $(\mu+\nu)$-by-ν matrix represented by

$$(c_0 + c_1 x + \ldots + c_\mu x^\mu)(1 + xy + x^2 y^2 + \ldots + x^\nu y^\nu),$$

and let

$$\lfloor c_0, c_1, \ldots, c_\mu \rceil_\nu$$

denote the ν-by-$(\mu+\nu)$ matrix represented by

$$(1 + xy + x^2 y^2 + \ldots + x^\nu y^\nu)(c_0 + c_1 y + \ldots + c_\mu y^\mu).$$

Then the ν-line minors

$$\Gamma_1, \Gamma_2, \ldots, \Gamma_p$$

of these matrices, $p = (\mu+\nu)_\nu$, in number, and the p different ν-factor products

$$C_1, C_2, \ldots, C_p$$

of the c's can be arranged by Gordan's rule * in such wise that for every i there is

$$\Gamma_i = C_i + a_{i, i-1} C_{i-1} + \ldots + a_{i0} C_0$$

the a's being integers. The Γ's are therefore linearly independent functions of the variables $c_0, c_1, \ldots, c_\mu$, and their linear independence subsists of course for $c_\mu = i$ too. By means of this we shall prove the following proportionality of $(m+n+r)$-line minors of the $(m+n+r)$-by-$(m+n+2r)$ matrix

$$M = \| (a_0, a_1, \ldots, a_m)_{n+r} (b_0, b_1, \ldots, b_n)_{m+r} \|$$

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* Gordan, P., "Ueber die Resultante," Math. Annalen, xlv (1894), pp. 405–409.

got from $(a_0, a_1, \ldots, a_m)_{n+r}$ by annexing to its $n+r$ columns the $m+r$ columns of $(b_0, b_1, \ldots, b_n)_{m+r}$ to the r-line minors of the r-by-$(m+n+2r)$ matrix

$$\mathbf{N} = \| [b_0, b_1, \ldots, b_n]_r \quad -[a_0, a_1, \ldots, a_m]_r \|$$

got from $[b_0, b_1, \ldots, b_n]_r$ by annexing to its columns those of $[a_0, a_1, \ldots, a_m]_r$, with changed signs.

Each $(m+n+r)$-line minor M' of M is equal to the product got by multiplying the eliminant R of

$$a_0 t^m + a_1 t^{m-1} + \ldots + a_m = 0$$
$$b_0 t^n + b_1 t^{n-1} + \ldots + b_n = 0$$

by that r-line minor of N which is the algebraical complement of M' in

$$\begin{vmatrix} (a_0, a_1, \ldots, a_m)_{n+r} & (b_0, b_1, \ldots, b_n)_{m+r} \\ [b_0, b_1, \ldots, b_n]_r & -[a_0, a_1, \ldots, a_m]_r \end{vmatrix}.$$

In the case where $m=2$, $n=2$, $r=1$, and also in the case where $m=2=n=r$, this theorem has been fully proved by Sir Thomas Muir.[*]

For ease in writing we also discuss only a special case, but the mode of our proof is applicable for every value of m, n, r. Taking $m=2$, $n=1$, $r=4$, we have

$$\mathbf{M} = \| (a_0, a_1, a_2)_5 \, (b_0, b_1)_6 \|$$

$$= \begin{Vmatrix} a_0 & \cdot & \cdot & \cdot & \cdot & b_0 & \cdot & \cdot & \cdot & \cdot & \cdot \\ a_1 & a_0 & \cdot & \cdot & \cdot & b_1 & b_0 & \cdot & \cdot & \cdot \\ a_2 & a_1 & a_0 & \cdot & \cdot & & b_1 & b_0 & \cdot & \cdot \\ \cdot & a_2 & a_1 & a_0 & \cdot & & \cdot & b_1 & b_0 & \cdot \\ \cdot & \cdot & a_2 & a_1 & a_0 & & \cdot & \cdot & b_1 & b_0 \\ \cdot & \cdot & \cdot & a_2 & a_1 & & \cdot & \cdot & \cdot & b_1 & b_0 \\ \cdot & \cdot & \cdot & \cdot & a_2 & & \cdot & \cdot & \cdot & \cdot & b_1 \end{Vmatrix}$$

and

$$\mathbf{N} = \| [b_0 b_1]_4 \quad -[a_0 \, a_1, a_2]_4 \|$$

$$= \begin{Vmatrix} b_0 & b_1 & \cdot & \cdot & -a_0 & -a_1 & -a_2 & \cdot & \cdot & \cdot \\ \cdot & b_0 & b_1 & \cdot & \cdot & -a_0 & -a_1 & -a_2 & \cdot & \cdot \\ \cdot & \cdot & b_0 & b_1 & \cdot & \cdot & -a_0 & -a_1 & -a_2 & \cdot \\ \cdot & \cdot & \cdot & b_0 & b_1 & \cdot & \cdot & -a_0 & -a_1 & -a_2 \end{Vmatrix}.$$

The representing polynome of M is

$$\mathbf{M}_{xy} = (a_0 + a_1 x + a_2 x^2)(1 + xy + x^2 y^2 + x^3 y^3 + x^4 y^4)$$
$$+ (b_0 + b_1 x)(y^5 + xy^6 + \ldots + x^5 y^{10}).$$

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[*] Muir, T., "Note on a Property of Bigradient Arrays connected with Sylvester's Dialytic Eliminant," Trans. R. Soc. S. Africa, xi (1923), pp. 101–104.

Our proof begins with the row-by-column product, MQ, of M and the matrix

$$Q = (c_0, c_1, c_2, c_3, 1)$$

represented by

$$Q_{xy} = (c_0 + c_1 x + \ldots + x^4)(1 + xy + \ldots + x^8 y^6).$$

The representing polynome $(MQ)_{xy}$ of this product is compounded of M_{xy} and Q_{xy}, that is to say, it is got by substituting in M_{xy} for the powers of y those polynomes depending on y by which the powers of x in Q_{xy} are multiplied. In detail the procedure is

$$(MQ)_{xy} = (a_0 + a_1 x + a_2 x^2)[H + xyH_3 + x^2 y^2 H_2 + x^3 y^3 H_1 + x^4 y^4 H_0]$$
$$+ (b_0 + b_1 x)[yK_0 + y^2 K_1 + y^3 K_2 + y^4 K_3 + (y^5 + xy^6)H]$$

where
$$H = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + x^4$$
$$H_3 = c_0 + c_1 x + c_2 x^2 + c_3 x^3 \qquad K_0 = 1$$
$$H_2 = c_0 + c_1 x + c_2 x^2 \qquad K_1 = c_3 + x$$
$$H_1 = c_0 + c_1 x \qquad K_2 = c_2 + c_3 x + x^2$$
$$H_0 = c_0 \qquad K_3 = c_1 + c_2 x + c_3 x^2 + x^3$$

This polynome is equal to the polynome which one gets by compounding

$$U_{xy} = (a_0 + a_1 x + a_2 x^2)(xH_3 + x^2 y H_2 + x^3 y^2 H_1 + x^4 y^3 H_0)$$
$$+ (b_0 + b_1 x)(K_0 + yK_1 + y^2 K_2 + y^3 K_3)$$
$$+ y^4 (1 + xy + x^2 y^2) H$$

with

$$R_{xy} = y + xy^2 + x^2 y^3 + x^3 y^4$$
$$+ x^4 [(a_0 + b_0 y^5) + x(a_1 + b_1 y^5 + b_0 y^6) + x^2 (a_2 + b_1 y^6)].$$

The determinant D corresponding to $(MQ)_{xy} = (UR)_{xy}$ is equal to the product got by multiplying the determinant D corresponding to U_{xy} by the determinant R

$$\begin{vmatrix} \cdot & 1 & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & 1 & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & 1 & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & 1 & \cdot & \cdot \\ a_0 & \cdot & \cdot & \cdot & \cdot & b_0 & \cdot \\ a_1 & \cdot & \cdot & \cdot & \cdot & b_1 & b_0 \\ a_2 & \cdot & \cdot & \cdot & \cdot & \cdot & b_1 \end{vmatrix} = \begin{vmatrix} a_0 & b_0 & \cdot \\ a_1 & b_1 & b_0 \\ a_2 & \cdot & b_1 \end{vmatrix}$$

which is the eliminant of

$$\left. \begin{array}{l} a_0 t^2 + a_1 t + a_2 = 0 \\ b_0 t + b_1 = 0 \end{array} \right\}$$

Now it is an elementary property of such determinants that, being given

$$U_{xy} = \sum_{i=0}^{\mu-1}\sum_{k=0}^{\mu-1} u_{ik}x^i y^k, \quad V_{xy} = \sum_{i=0}^{\mu-1}\sum_{k=0}^{r-1} v_{ik}x^i y^k, \quad W_{xy} = \sum_{i=0}^{r-1}\sum_{k=0}^{r-1} w_{ik}x^i y^k,$$

the determinant corresponding to $U_{xy} + y^\mu V_{xy} + x^\mu y^\mu W_{xy}$ is equal to the product of the determinants which correspond to U_{xy} and W_{xy}. But in the case of the above U_{xy} and of

$$V_{xy} + x^7 W_{xy} = x^3(1 + xy + x^2 y^2 + x^3 y^3)H,$$

the determinant of W_{xy} being evidently $= 1$, the determinant Δ corresponding to U_{xy} is equal to the determinant which corresponds to

$$\begin{aligned}
G_{xy} &= U_{xy} + y^7(V_{xy} + x^7 W_{xy})\\
&= (a_0 + a_1 x + a_2 x^2)\,(xH_3 + x^2 y H^2 + x^3 y^2 H_1 + x^4 y^3 H_0)\\
&\qquad + (b_0 + b_1 x)\,(K_0 + yK_1 + y^2 K_2 + y^3 K_3)\\
&\qquad + (y^4 + xy^5 + x^2 y^6 + \ldots + x^6 y^{10})H\\
&= (a_0 + a_1 x + a_2 x^2)x(1 + xy + x^2 y^2 + x^3 y^3)H\\
&\qquad + [b_0 + b_1 x - x^5(a_0 + a_1 x + a_2 x^2)]\,(K_0 + yK_1 + y^2 K_2 + y^3 K_3)\\
&\qquad + (y^4 + xy^5 + x^2 y^6 + \ldots + x^6 y^{10})H.
\end{aligned}$$

G_{xy} is compounded of

$$\begin{aligned}
H_{xy} &= [b_0 + b_1 x - x^5(a_0 + a_1 x + a_2 x^2)]\,(K_0 + yK_1 + y^2 K_2 + y^3 K_3)\\
&\qquad + (y^4 + xy^5 + \ldots + x^6 y^{10})H
\end{aligned}$$

and $H'_{xy} = 1 + xy + \ldots + x^{10}y^{10} + x^5(a_0 + a_1 x + a_2 x^2)\,(1 + xy + x^2 y^2 + x^3 y^3).$

Finally H_{xy} is compounded of

$$\begin{aligned}
K_{xy} &= [b_0 + b_1 x - x^5(a_0 + a_1 x + a_2 x^2)]\,(1 + xy + x^2 y^2 + x^3 y^3)\\
&\qquad + (y^4 + xy^5 + \ldots + x^6 y^{10})H
\end{aligned}$$

and $K'_{xy} = K_0 + yK_1 + y^2 K_2 + y^3 K_3 + x^4 y^4 + \ldots + x^{10}y^{10}.$

The 11-line determinants corresponding to H'_{xy} and K'_{xy} being equal to 1, the determinants corresponding to H_{xy} and K_{xy} must be equal to Δ. In this way there must exist between the determinant D, which belongs to $(MQ)_{xy}$, and the determinant Δ, which belongs to K_{xy}, the relation

$$D = R\Delta.$$

D and Δ both are, according to the theorems of Binet-Cauchy and Laplace respectively, homogeneous linear functions of the 5-line determinants of $Q = (c_0, c_1, c_2, c_3, 1)_7$. Hence, on making comparison, we at once see the relation between the $m + n + r = 7$-line determinants of M and the $r = 4$-line determinants of N, the determination of the signs being also very easy.

NOTE ON THE FOREGOING BY SIR THOMAS MUIR.

The advantage of Professor Kürschák's method over mine lies in the fact that, whereas I obtain directly the co-factor of R in only a limited number of cases, his gives it in every case. To make this and the details of the contrast clear, I herewith append a jotting of my mode as applied to the special case chosen by him :—

The product of the resultant of

$$\left.\begin{array}{l} a_0x^2+a_1x+a_2=0 \\ b_0x+b_1=0 \end{array}\right\} \text{ and } \left\{\begin{array}{l} a_0x^2+a_1x+a_2=0 \\ c_0x^4+c_1x^3+c_2x^2+c_3x+c_4=0 \end{array}\right\},$$

that is to say,

$$R_{21} \begin{vmatrix} a_0 & . & . & . & c_0 & . \\ a_1 & a_0 & . & . & c_1 & c_0 \\ a_2 & a_1 & a_0 & . & c_2 & c_1 \\ . & a_2 & a_1 & a_0 & c_3 & c_2 \\ . & . & a_2 & a_1 & c_4 & c_3 \\ . & . & . & a_2 & . & c_4 \end{vmatrix}$$

= resultant of $a_0x^2+a_1x+a_2$ and $(b_0x+b_1)(c_0x^4+ \dots +C_4)$

$$= \begin{vmatrix} a_0 & a_1 & a_2 & . & . & . & . \\ . & a_0 & a_1 & a_2 & . & . & . \\ . & . & a_0 & a_1 & a_2 & . & . \\ . & . & . & a_0 & a_1 & a_2 & . \\ . & . & . & . & a_0 & a_1 & a_2 \\ b_0c_0 & b_0c_1+b_1c_0 & b_0c_2+b_1c_1 & b_0c_3+b_1c_2 & b_0c_4+b_1c_3 & b_1c_4 & . \\ . & b_0c_0 & b_0c_1+b_1c_0 & b_0c_2+b_1c_1 & b_0c_3+b_1c_2 & b_0c_4+b_1c_3 & b_1c_4 \end{vmatrix}$$

$$= \begin{Vmatrix} 1 & . & . & . & . & . & . \\ . & 1 & . & . & . & . & . \\ . & . & 1 & . & . & . & . \\ . & . & . & 1 & . & . & . \\ . & . & . & . & 1 & . & . \\ . & . & . & . & c_0 & c_1 & c_2 & c_3 & c_4 & . \\ . & . & . & . & . & c_0 & c_1 & c_2 & c_3 & c_4 \end{Vmatrix} \begin{Vmatrix} a_0 & . & . & . & b_0 & . & . & . \\ a_1 & a_0 & . & . & b_1 & b_0 & . & . \\ a_2 & a_1 & a_0 & . & . & b_1 & b_0 & . \\ . & a_2 & a_1 & a_0 & . & . & b_1 & b_0 & . & . \\ . & . & a_2 & a_1 & a_0 & . & . & b_1 & b_0 & . \\ . & . & . & a_2 & a_1 & . & . & . & b_1 & b_0 \\ . & . & . & . & a_2 & . & . & . & . & b_1 \end{Vmatrix}$$

$$= c_0{}^2 |89te| + c_0c_1 |79te| + c_0c_2 |78te| + c_0c_3 |789e| + c_0c_4 |789t| + \dots + c_4{}^2 |6789|.$$

Equating co-factors of $c_0{}^2$, c_0c_1, . . . we see at once that *fifteen* of the primary minors of the second 7-by-11 array contain the factor R_{21} : but though, as a consequence of this, all the other primary minors are known to have the same factor, there is nothing to show in their cases what the co-factors are.
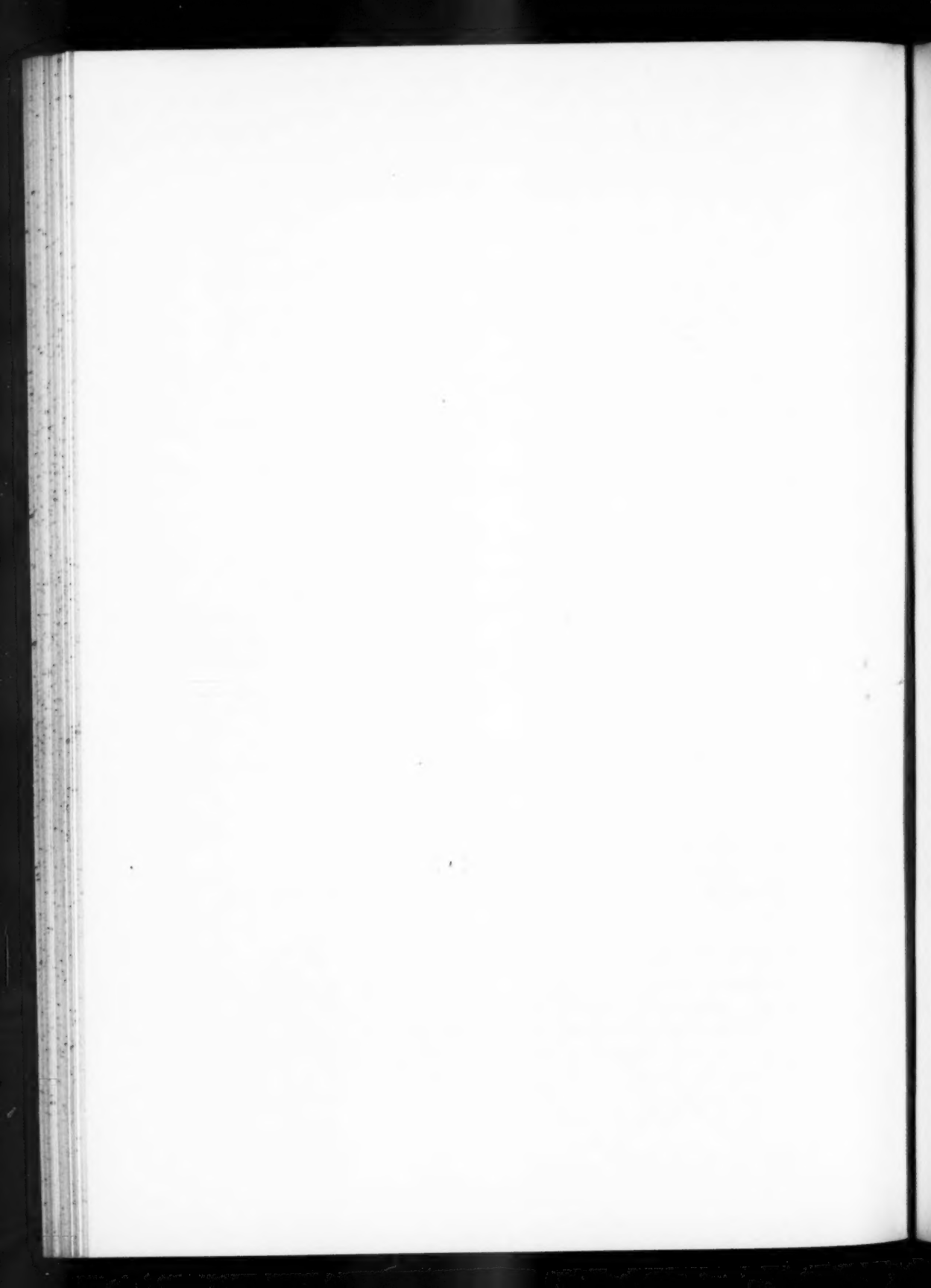
A PROTOZOAL PARASITE (*CHLOROMYXUM THYRSITES*, SP. N.) OF THE CAPE SEA-FISH, THE " SNOEK " (*THYRSITES ATUN*, Euphr.).

By J. D. F. GILCHRIST.

The Cape " Snoek " *Thyrsites atun*, a large pike-like fish, of great economic importance in South Africa, is frequently found to be affected in a peculiar way. The flesh becomes soft, and in some cases even assumes a liquid form. The fish in this condition are known to Cape fishermen as " Pap Snoek," and, as they constitute about 5 per cent. of the total catch of Snoek in the chief season for this fish (May–June), their occurrence is a serious loss to the fishing industry. The fishermen believe the condition is brought about by the fish not being properly killed when caught by the inexperienced and unskilled, the softening of the flesh being the result of the fish being bruised in struggling about in the bottom of the boat. Microscopical examination of the affected tissue, however, showed that the condition is more probably due to protozoal parasites resembling *Chloromyxum*. These had clearly four polar capsules, as in this genus, though certain facts in its life-history seem to indicate that it should be separated from this genus.

It is not improbable that the parasite is identical with a protozoal parasite found by Dr. J. Burton Cleland (Journal and Proc. Roy. Soc., N.S. Wales, vol. xliv, 1910) in the Australian " Barracoota," which is believed to be the same species of fish as the Cape " Snoek." The parasite brings about the same destruction of the tissue of the host, the fish so affected being known as the " Milky Barracoota." The spores fixed by drying were examined by Dr. Cleland, and from their general appearance were believed to represent a species of *Chloromyxum*.

In the year 1917 I drew up a short note on the subject, and exhibited some specimens of the parasite and affected tissue at a meeting of this Society. The complete life-history has not yet been ascertained, but, as suitable material and opportunity are not readily obtained for pursuing the investigation, the following results are recorded :

Various methods were employed, chiefly sublimate-acetic and others such as sublimate-alcohol-acetic, sublimate-formalin-acetic, 10 per cent. formalin, and osmic acid. Simple drying on the slide also afforded some

useful information, and was a very convenient diagnostic method, along with methylene blue staining. In addition to smears of the tissue, sections of varying thickness down to 4 μ were made, and mostly stained with hæmatoxylin and eosin; staining intra-vitam with methylene blue was also found instructive with regard to some details.

The Spore.—The usual appearance of the spore in fixed material is very characteristic (fig. 1, *a*). The four unequal polar capsules were readily seen with methylene blue staining, and, in hæmatoxylin preparations, four nuclei associated with them were conspicuous; near the apices of the polar capsules was a greater or less amount of protoplasm (presumably the sporoplasm) (*sp*, in fig. 1, *c*). Surrounding the whole there usually appeared a
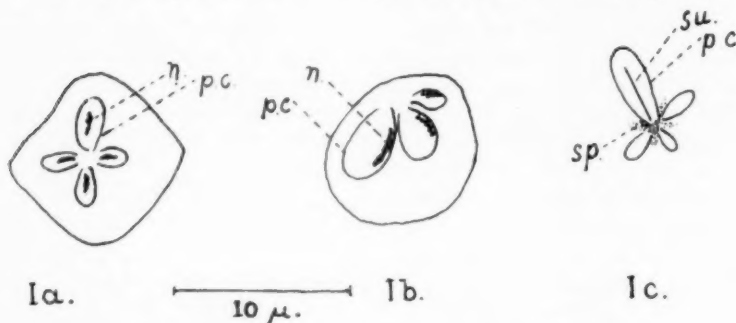
FIG. 1a–1c.—Spores of *Chloromyxum* preserved and stained.

quadrangular space, which might represent the outline of the spore. Though usually quadrangular it was often rounded or lenticular, and as frequently absent altogether (fig. 1). It was not till these bodies were examined in a living condition that the existence of a definite wall was determined, and its shape made out. They can best be seen in a living spore, which happens to be rolling about in the fluid in which it is examined. It was then seen that the spore was dome-shaped, with a broad, flattened base which is drawn out into four angular projections (fig. 2). These projections have clearly defined edges; their angles are sharp and acute, and do not stain with any of the reagents employed. They appear to be thin but solid in their distal half, an appearance which may, however, be due to the walls coming into contact with each other at these points.

The shape of the spore is not constant though usually of the stellate outline described. One of the rays opposite the larger polar capsule is often slightly longer than the other, and that opposite the smaller capsule is sometimes a mere blunt projection (fig. 2, *b*). The spore has therefore a bilateral symmetry, less marked, however, than the radial symmetry.

Exceptionally all the rays are blunt.   Cases have been observed in which the whole spore wall assumes a vesicular form, and this may be an earlier or later stage of development.

That the spore wall is thin and somewhat membraneous seems to be indicated by cases in which the spore has been attacked by bacteria.   After
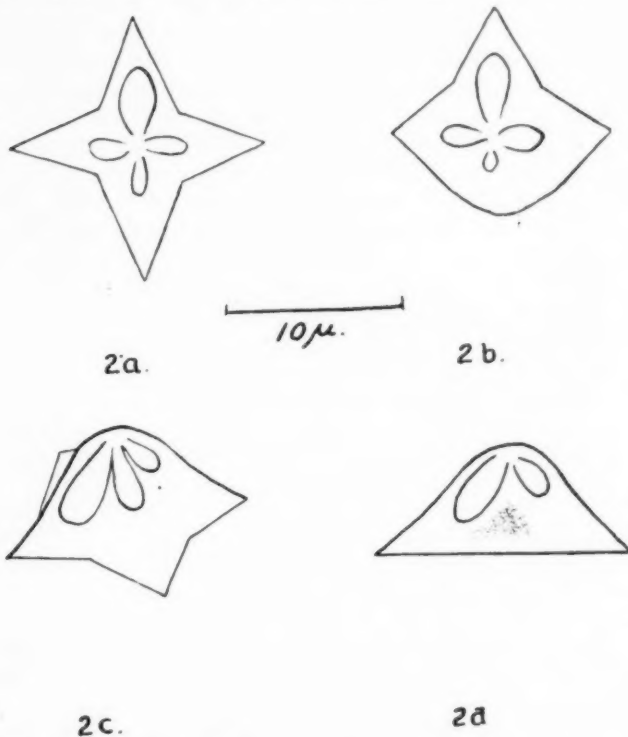
Fig. 2a–2d.—Spores of *Chloromyxum thyrsites* in the living state.

three or four days these usually appear, and, after attacking the muscular debris, attack the spores, removing the whole of the inside and leaving a very thin outer covering.   In some respects this spore wall or sporocyst differs from what is found in Myxosporidia.   In the first place, there is no indication of a suture dividing it into two shell-like halves, as in many other forms ;   and, secondly, it is not resistant to strong acids, as are the shells of other Myxoporidian spores.   Further, it is readily ruptured when well shaken in water.

The size of the spore varies, but is usually about 12 μ from the tips of opposite projections. The height is about 8 μ.

Polar Capsules.—These are the most conspicuous features of the spore, both in the fresh and preserved condition. They readily stain with methylene blue in both cases. They are separate bodies, appearing, when alive, of a bluish colour under the microscope by transmitted light, and bronze yellow by reflected light. They are four in number and ovoid in shape, with a pointed end where they approach each other at the apex of the spore, as in the genus *Chloromyxum.* They are invariably of markedly unequal size, the largest being usually about 3 μ in length and 2 μ in breadth, and occupying the greater part of the quadrant of the spore in which it occurs. Opposite is the smallest, about half its size, and on each side is one of intermediate size. The walls of these capsules are clear, glistening, and smooth, without differentiation; but in some cases a clear narrow line was seen to proceed from the anterior end of the capsules, being lost towards the posterior and rounded end, suggesting the existence of a suture (fig. 1, *c, su*). In some methylene blue preparations a clear elongate space could be seen, evidently the opening for the discharge of the filament. The wall of the capsule is not opaque, as in most Myxosporidian spores (Gurley), the filaments being visible through them when methylene blue is used as a stain. Strong ammonia water and glycerine render them slightly more transparent, but not in a marked degree. Iodine water renders them much more transparent, and the filaments, in some so treated, could be made out. Several cases were seen in preparations, in which the polar capsules were isolated from each other and with no traces of the other parts of the spore. Some of these had their filaments extruded, and, in one or two cases, single polar capsules were found completely isolated and with extruded filaments (fig. 3).

Filaments.—As stated above, the filament, coiled up in the polar capsule, can be seen in living spores stained in methylene blue. The coils are numerous and occupy the greater part of the interior of the capsule. This was usually seen in the largest capsule, less often in the smaller ones, in which the staining showed a granular appearance of the contents, perhaps indicating that the capsules mature at different periods.

The extrusion of the filaments is very uncertain. On several occasions all the spores (several hundreds) placed in water on a slide extruded their filaments with a sudden explosion on the addition of weak acid, but this did not often happen, though the same experiment was repeated several times on other spores. Any kind of acid seems to be equally efficient in securing this result. They were sometimes seen extruded in preparations fixed by heating on the slide. Strong ammonia or hot water were not found to cause extrusion of filaments, which, however, seems to be more a matter

of maturity than of the exciting agent employed.   The extruded filaments often stain well with methylene blue.   All filaments of the four capsules are sometimes extruded, at other times three, two, or only one (fig. 3).

The completely extruded filament is very long, being almost five times the length of the capsule, which in one case was 3μ, the filament being 15μ ; in another the capsule was also 3μ, but its filament 20μ measured in a bent condition, so that it was about eight times the length of the capsule.

The function performed by the filaments in the life-history of these Myxosporidia is not known from any actual observation, so that the fact

3a.   *3b*   *3c.*   *3d*   *3e.*   *3f.*

$10 \mu.$
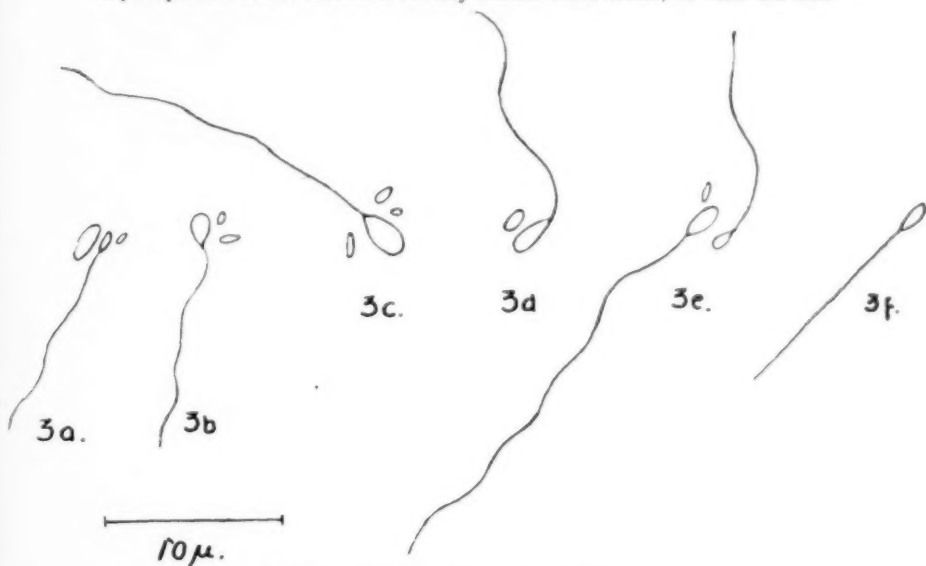
FIG. 3*a*–3*f*.—Polar capsules with extruded filaments.

noted, that the discharging filaments enable the spore to clear itself of the surrounding material in which it is embedded and float freely in the water, may be of some value.   A clearly defined nucleus was always associated with each of the polar capsules.   In certain lateral views, as well as by focussing downwards in other views, it was seen that these nuclei were very elongate, a characteristic of the nuclei of polar capsules when in an advanced stage of development.

Sporoplasm.—The remaining space of the cavity of the spore is occupied by a protoplasmic mass which represents the sporoplasm.   It is very difficult to make out in the whole spore, as it lies between and below the polar capsules.   It could, however, be seen in a lateral view of the living spore,

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stained in methylene blue (fig. 2, *d*), and was very distinct in cases where the spore had apparently been ruptured and the polar capsules separated from each other (fig. 1, *c*). In such cases it was often clearly marked off from the polar capsules, as it stained a bright blue and the polar capsules green in some methylene blue preparations. This sporoplasm had a vacuolated appearance, though there did not appear to be any iodine-staining vacuoles.
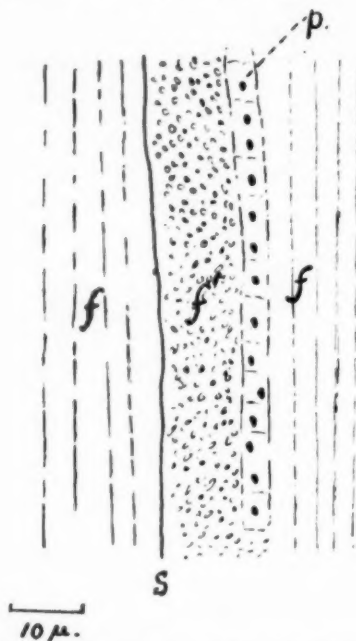
Fig. 4.—Longitudinal section of infected muscle, showing trophozite stage of parasite. *p*; Muscle fibre, *f*; Disintegrated muscle fibre, *f′*; Sarcolemma, *s*.

No trace of any nuclei were found in it by a nuclear stain in such cases, though in the unruptured spore, when treated with a nuclear stain, a number of bodies much smaller than the elongate nucleus were seen.   In connection with this it may be noted that in the fresh spore, more especially if treated with a solution of potassium iodide, small dark bodies were seen in the spore outside the polar capsules.   They were most clearly seen in the angular projections of the spore, and might be excretory particles.

Trophic Stages.—In some smears of the diseased muscle fixed in various ways, small nucleated bodies were to be seen along with the spores, and

these appeared to be the trophozoite stages of the parasite. They each had a single well-defined nucleus and a homogeneous protoplasmic body with well-defined outlines, usually rounded. These bodies were best shown, however, in longitudinal sections of the infected muscle (fig. 4), and here their mode of multiplication and the effect which they produce on the muscular tissue of their host were clearly demonstrated. They may occur singly, but are usually in long chains of cells between the muscle fibre and the sarcolemma. These chains are readily recognised in longitudinal sections, and usually consist of about ten to twenty cells. In a single section 4μ in thickness, as many as 50 were counted in a chain. The outline of each cell is usually well defined, except in cells apparently in the process of division. Groups of small cells also occur in the disintegrated muscle surrounded by connective-tissue (fig. 5). In this case also they were distinct from each other, and no large multinucleate bodies were found, such as occur in the corresponding stages of some other Myxosporidians. These
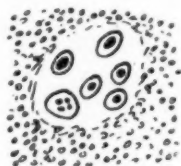
FIG. 5.—Trophozoites in groups.

small mononucleate bodies or meronts were irregular or amoeboid in outline when separate or in groups, and measured about 3 to 4μ in diameter. When in chains they were rectangular, and measured about 5μ in length and 4μ in breadth. The protoplasmic body appeared quite homogeneous, and the nucleus rounded, with no marked chromatin differentiation that could be seen, or with slight indications of network. The nuclei were, however, often elongate when the meronts occurred in chains, and attained a length of 2μ. In some a clear vesicular projection was seen, the significance of which was not apparent.

Propagative Stages or Spore Formation.—In most of the Myxosporidia the Myxosporidium or trophozoite (binucleate in its early free stages) increases greatly in size. The nuclei divide repeatedly without a division of the protoplasm, to form multinucleate apocytes which may bud. The protoplasm then becomes aggregated in spherical masses round each nucleus to form a pansporoblast or archispore, from which, by subdivision of the nucleus, several sporoblasts arise, each giving rise to a spore. In this parasite the process seems to be much simplified. Each individual is

mononucleate, and that from each a single spore is formed seems to be indicated by the following observations, which, however, require further investigation with fuller material. In some of the meronts the nucleus shows indications of a differentiation in its chromatin elements, which become broken up into small parts of unequal size. Another stage observed, apparently a subsequent one, is that in which the nucleus is divided up into still smaller and more numerous parts, scattered throughout the cell. In one case seven such subdivisions were counted with certainty, and in another case eight, though there may have been more. The stage subsequent to this, and closely approaching the spore stage already described, is one in which four distinct and larger nuclei are to be seen placed at about equal distance from each other (fig 6, *a*, *b*). No aggregation of the protoplasm round these was observed in some, but in others this appeared to be the case (fig. 6, *c*), so that the whole cell appeared to be divided into four parts. This appearance, however, might quite well have been due to other causes,
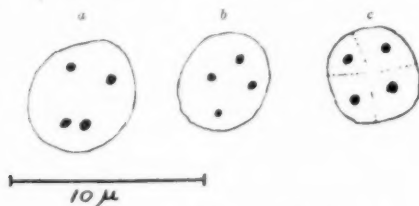
FIG. 6a–6c.—Later stages of Trophozite.

such as the presence of four vacuoles, destined to be the polar capsules. That these appear early may be indicated by a cell in which at least two nuclei were seen, and two large vacuoles, a solitary case, however, out of many hundreds examined, so that much importance cannot be attached to it.

The next stage observed was that of the fully formed spore, the structure of which has already been described. The early vegetative stages and the spores were found in great abundance, the intermediate stages above mentioned being seldom encountered. From this it may be inferred that the formation of spores is a very rapid process, and this is borne out by the great increase observed in the number of spores after the death of the host.

The peculiarity in the development, as compared with other species of Chloromyxum, is that the vegetative form is mononucleate and apparently becomes a sporoblast from which a single spore is formed. This, though unusual, is not unknown in other species, for in *C. cristatum*, according to Leger, each individual produces only one spore, the individuals in this case, however, being multinucleate.

The further development of the spores is unknown. They have been

found in fish which have been eighteen days in salt. In fish which have been salted and sun-dried they are still recognisable, though most of them have become disintegrated. In such cases it was observed that the polar capsules had become separated from each other. That they are still alive is uncertain, though polar filaments were extruded on irritation, for it is recorded that spores which have been preserved in alcohol have extruded their filaments.

Only the above-mentioned stages (trophozite to spore formation) are as yet known. Whether infection of the fish is through the alimentary tract, blood or lymph system, is not known. That it is not through the injured epidermis, as in many other cases, is fairly obvious. If the parasite has a second host, it seems probable that this may be some large sea animal, such as the seal or the shark, which devour this fish. An observation, however, on the advanced stage of the spores suggests another and more probable second host. It was noted that after three or four days the infected flesh was invaded by the bacteria of putrefaction. In sea water the tissue was in this way gradually broken up, and the spores, still alive, were released and became free in the water. They may thus infect other fishes or even marine invertebrates. Should this second host be the food of the Snoek, the parasite would readily be conveyed again to the first host. The most probable secondary host fulfilling these conditions is the sardine or pilchard (*Sardina sagax*), on which the Snoek feeds almost exclusively, and it would be well worth while to examine the gills, alimentary tract, etc., for traces of the spores, as these can be so readily recognised by methylene blue staining. The peculiar form *Coccomyxa* occurs in the gall bladder of the European sardine, which is closely related to the Cape sardine.

Pathological Effects.—The disease is most prevalent in the " fat snoek," which appears usually in May and June. In the " poor snoek " season, when the fish are in poor condition, and often infested with characteristic parasitic worms in the flesh and elsewhere, the " pap " condition is not so often seen.

The disease causes great damage to the fishing industry, as the pap-snoek, if badly infected, which they frequently are, cannot be salted and dried. If only slightly infected, they can be cured by salting and drying; and indeed it would appear from microscopic examination of apparently healthy fish that the parasite occurs in most of the snoek caught, as on one occasion out of twelve fish taken at random, and considered perfectly healthy, spores of the parasite were found in eight.

The parasite does not form harmless cysts, nor is it an intracellular one, which, by " diffuse infiltration," destroys quickly the tissue it penetrates. It attacks the muscle fibres from the outside as a rule, and in one instance only was it found penetrating the muscle fibre. This is probably the reason

why so many fish, considered to be perfectly normal, were found on micro-
scopic examination to be infected, sometimes heavily, without seriously
imparing the functional activity of the muscles, and may also explain the
statement of some fishermen that any snoek, if kept for over twenty-four
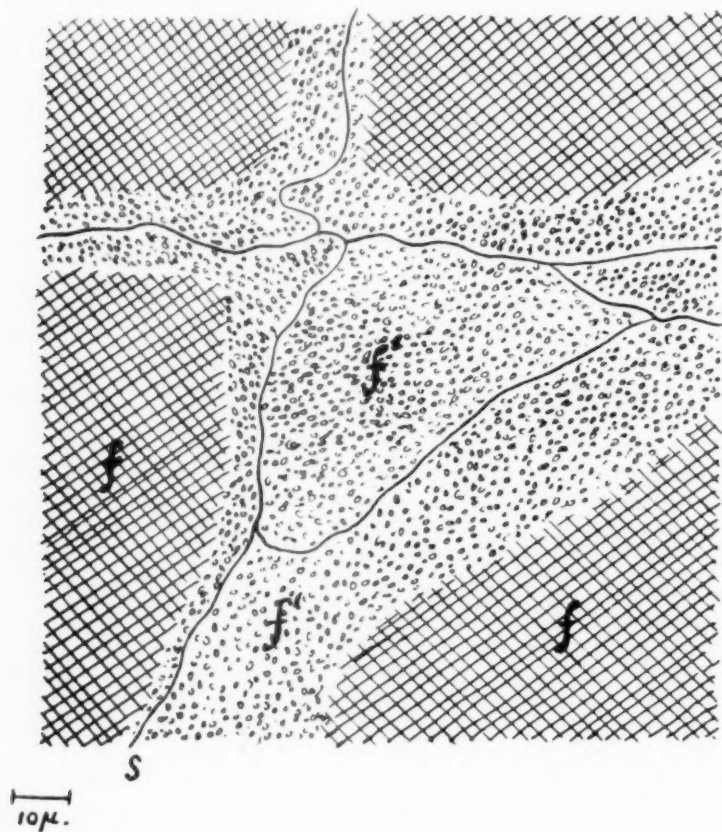
Fig. 7.—Transverse section of infected muscle.   Muscle fibre, *f*; Disintegrated
fibre, *f'*; Sarcolemma, *s*.

hours unpickled, will become " pap," probably owing to the very rapid
formation of spores after the death of the fish.   Most species of *Chloromyxum*
are found in the cavities of body, such as the gall bladder, cœlom, and urinary
bladder, but some are found in the muscular system, as, for instance,
C. quadratum, in *Sygnathus acus, Clupea harengus, Abramis brama, Trachurus*

trachurus, where, however, they do not appear to do extensive damage. This species, however, attacks the muscle tissue in such a way that it must apparently destroy many fish in the sea. In section the destroyed muscle appears as granular or hyaline material between the muscles (fig. 7). When the badly infected fish is cut open, the muscles are somewhat soft and have a characteristic glazed or glistening appearance. Then they quickly assume a fluid condition, like thick milk. One such specimen, kept in the laboratory for two days, developed this condition, and fishermen state that on some occasions of the fish when picked up from the bottom of the boat, where they had lain a few hours after capture, nothing remained but skin and bones, the flesh flowing away in a milky stream. No bacteria are at first found in this fluid substance, and it is quite free from any odour of decay. A day or two later, however, bacteria of putrefaction attack both the diseased tissue and the parasites.

The Snoek normally appears in immense numbers at the Cape, but some years ago the fishing industry suffered a great calamity in the practical disappearance of the fish. This was put down to a variety of causes, such as change of currents, and netting operations, especially trawling. It was suggested also that the catching of immature fish might be the cause, and a law was passed imposing a size limit. It seems not improbable that the scarcity of the fish was due to this protozoal disease.

Inquiries have been made by means of circulars distributed to fishermen and others regarding the " pap snoek." Amongst other questions asked was whether or not the eating of " pap snoek " had any ill effect on the consumer ? Most of those who replied to this query stated that no such effects had been observed. Others, again, said that it produced a kind of sickness. I learned also that the country people who buy these " pap snoek," on account of their cheapness, suffer from some kind of eruption or boils on the skin. The medical authorities of the city of Cape Town condemn " pap snoek " as unfit for human food, but apparently for no definite reason except its unwholesome appearance. Some of the correspondents stated that the eating of the affected fish produced leprosy.

The investigation of the life-history of the parasite seems to be of considerable zoological interest as well as of economic importance, and it is hoped that it may be followed up.

STUDIES IN THE MORPHOLOGY OF *SELAGINELLA PUMILA*, SPRING.

PART III.

By A. V. DUTHIE.

(With twenty-six Text-figures.)

In the Stellenbosch district the megaspores of *Selaginella pumila*, which are shed before the formation of prothallial tissue, lie dormant on the soil during the summer months and germinate after the early winter rains. At the beginning of May hundreds of sporelings may be found among young
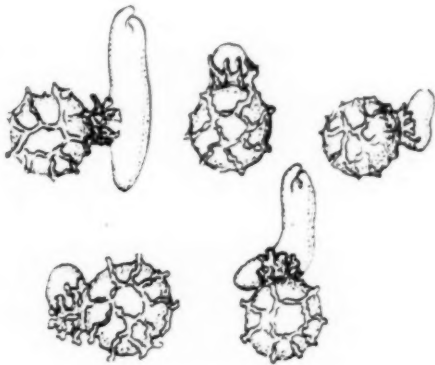
FIG. 1.

grasses, flowering plants of *Pauridia hypoxidioides*, seedlings of Dicotyledons, moss and liverwort thalli, etc. (fig. 1). The spores do not germinate simultaneously, and young sporophytes continue to appear during a period of several weeks. In a series of laboratory cultures the first sporophytes visible with the binocular microscope were observed twenty-six days after the sowing of the spores. Here, too, germination was found to be very irregular, fresh sporophytes continuing to appear for some seven weeks.

This marked irregularity in the development of the embryos is doubtless due, in part, to the spores being shed in different stages of maturity.

Numerous experiments were carried out in order to test the capacity of the germinated megaspores to retain their vitality when dried for a length of time. Cultures of spores, some of which showed apical prothalli and apparently fertilised archegonia, were allowed to dry out completely at room temperature and to remain dry for several months. Other cultures were kept moist until the first sporelings were observed and then dried. In about a fortnight after re-moistening these cultures, sporophytes were seen protruding from the megaspores and new sporophytes continued to appear for some time. It is probable that some of these sporophytes had begun to segment before the drying of the cultures, had retained their vitality unimpaired during the time of drought, and had resumed their development when moisture was once more available. The same conclusion has been arrived at by the investigators of certain other species. Campbell (9), for example, writes : " From some partial observations made by the writer upon spores of a species (probably L.* (sic) Bigelovii) from the dry region of Southern California, it looks very much as if, in this species, the spores became completely dried up after the embryo had already attained some size, and that the spores remained in this condition during the dry season, the embryo resuming its growth again in the autumn."

The development of sporophytes in archegoniate prothalli which have undergone prolonged desiccation may also be the result, in part, of delayed normal fertilisation ; for it has been shown that in this little species male as well as female prothalli in advanced stages of development can endure prolonged and intermittent drying without losing their vitality (12). The possibility, too, of apogamous development of embryos, which will be referred to again later, should not be lost sight of.

Small embryos, which have emerged slightly beyond the curtain-like projection of the spore coat and hence are visible without dissection of the spores, will on drying retreat completely within the spore coats, where their protection is probably almost as perfect as in the cases considered above. Experiments also indicate that somewhat larger sporophytes may recover completely after several days of drought. It would thus appear that we may have in S. pumila an approach to the condition obtaining in seed plants, where as a rule embryo development is interrupted by a period of dormancy of longer or shorter duration.

In old fertilised and unfertilised archegonia the upper tier of neck cells usually becomes strongly thickened. This thickening may extend to the lower tier as well and even to the cavity of the venter (figs. 2 and 3). Several sections were noticed showing this condition, but it was not possible

* This is obviously a misprint for S. Bigelovii.

to decide whether the archegonium had been fertilised or not. Holloway (19) figures a section through the prothallus of *Tmesipteris* in which the cutinisation of the outer walls of the vegetative cells had extended over the persistent lowest tier of neck cells of an old, unfertilised archegonium and round the cavity of the venter. In old cultures of *S. pumila* it is not unusual to find all the prothallus cells more or less thick-walled. Several longitudinal sections of segmenting embryos examined showed the heavily thickened neck cells of the archegonium in close contact, resembling very closely Bruchmann's figures of apogamously developed embryos of *S. rubricaulis, S. spinulosa*, and *S. helvetica* (6, 8). In no instance, however,
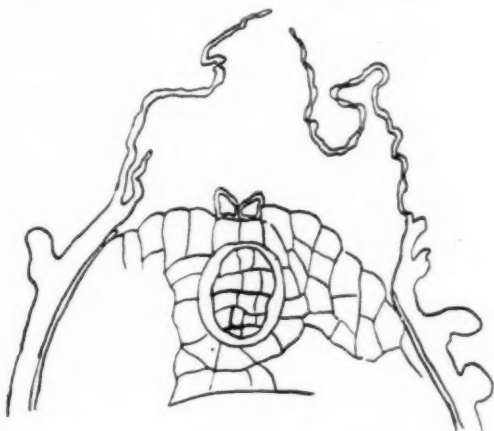
FIG. 2.   FIG. 3.

was a segmenting embryo found to lie below entire or degenerating canal cells as figured by Bruchmann for *S. rubricaulis*. In the absence of conclusive evidence of apogamy in *S. pumila*, it is wiser to look upon such apparently closed archegonial necks as the result of the sections not being median or possibly of closing of the neck after the entrance of the spermatozoid.

Embryology.—One of the most striking features of the embryology of *S. pumila* is the absence of a suspensor. Unfortunately no good preparations were obtained of the earliest segmentation of the fertilised egg, but older embryos show no trace of this organ. The section in fig. 4 was slightly oblique, the neck cells of the archegonium appearing in the adjoining section. Figs. 5 to 9 represent a series of consecutive transverse sections passing through a fertilised archegonium. The sections figured in 5 and 6 have passed through the upper and lower tiers respectively of the arche-

gonial neck; those figured in 7, 8, and 9 have passed through the venter
with its enclosed embryo.   Fig. 9 shows an older embryo after the organisa-
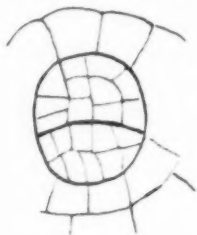
Fig. 4.
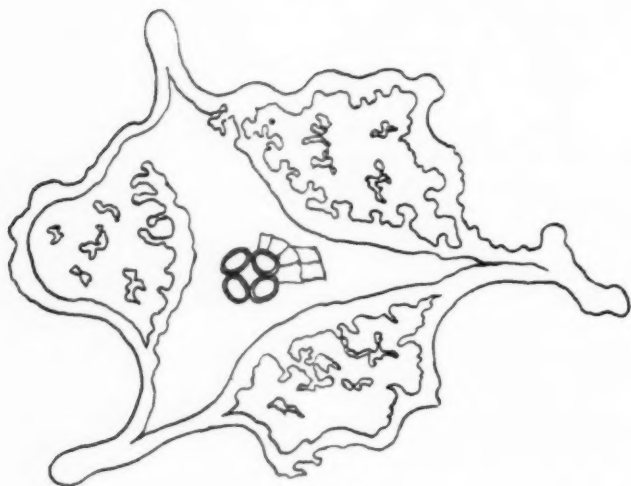
Fig. 5.
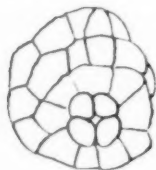
Fig. 6.

tion of the cotyledons.   The section is slightly oblique and the lower part
is somewhat crushed.   The upper part of the prothallial tissue continues

to keep pace for a time with the growth of the embryo, forming about it a delicate veil which is finally ruptured by the emerging hypocotyl and root (figs. 10–13). This prolonged growth of prothallus tissue about the
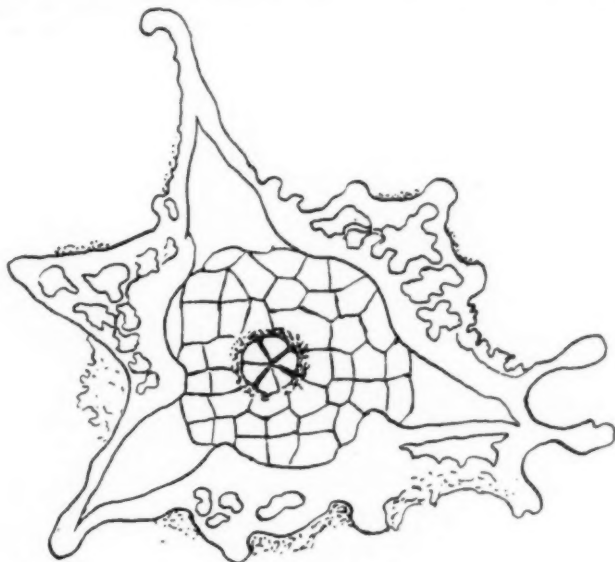
FIG. 7.

enlarging embryo, as well as the absence of a suspensor, are suggestive of *Isoetes*. The curtain-like outgrowth of the spore membrane already referred to also surrounds the base of the sporeling (figs. 11, 13). This outgrowth is seen in transverse section in figs. 5 and 7.

FIG. 8.

FIG. 9.

As has already been noted (12), the female prothallus is restricted to a small apical cap of tissue, the greater part of the megaspore being occupied by a large, non-septate storage cavity. The suctorial foot is a very striking feature of older embryos, and its surface cells are of large size and markedly papillate (figs. 12, 14). In some of the prothalli examined these large absorbing cells of the foot had projected more than half-way down into the
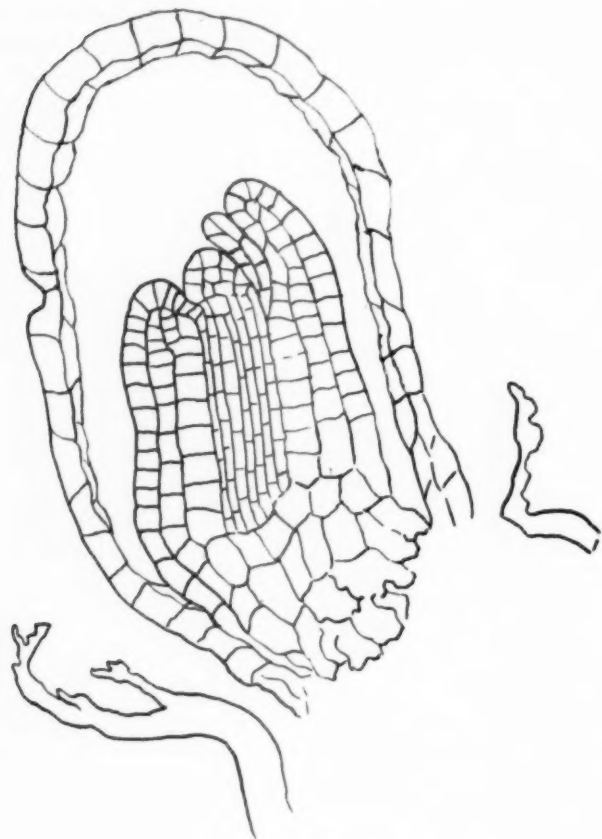
Fig. 10.
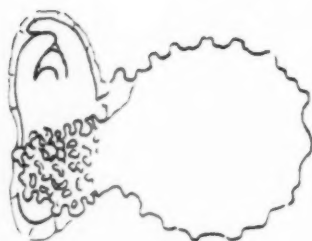
Fig. 11.

spore cavity.   In oblique sections the resemblance to a large-celled storage prothallus was very striking.

Cotyledons.—That the cotyledons do not appear simultaneously nor yet actually opposite to each other is very noticeable in advanced intra-sporal
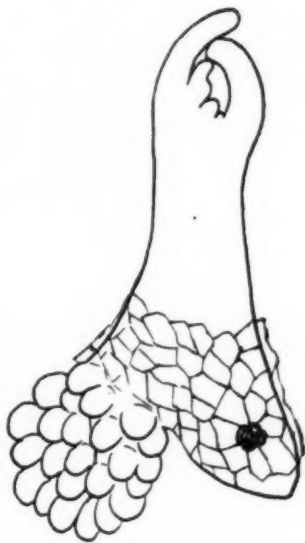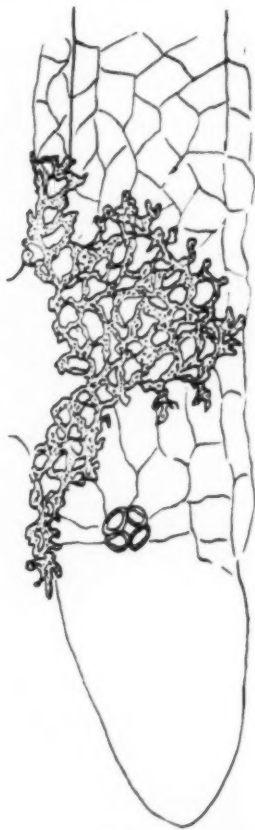
FIG. 12.   FIG. 13.

embryos, and may also be observed in sporelings before the inner faces of the laminae have separated (figs. 10–12).   The inequality in size of the cotyledons is also strongly marked even after they have unfolded, though as the result of continued growth in the younger of the two the expanded cotyledons usually come to be equal or sub-equal in size (fig. 16).   The enlarged base, which is so striking a feature of the ordinary vegetative

leaf, is much less prominent in the cotyledonary leaves, though even here it is occasionally fairly well developed (fig. 15).   Stomata are confined to
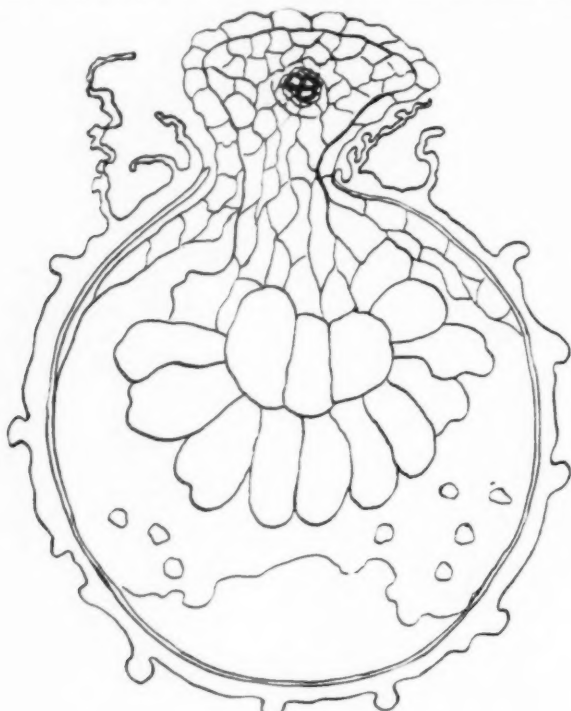
Fig. 14.

Fig. 15.

Fig. 16.

the aligular surface.   They occur on and near the leaf-margin, over the surface of the lamina, especially in the neighbourhood of the vein, and at

the leaf-base. In this last situation they are few in number as compared with the conspicuous group at the base of the vegetative leaf. Chloroplasts occur in the epidermal cells. The vascular bundle is poorly developed and dies out before reaching the leaf-apex. No transfusion tracheides were observed in any of the cotyledons examined.

Hypocotyl.—The length of the hypocotyl varies from 4 to about 10 mm., according as the spore germinates on or below the surface of the soil and the sporeling is exposed to weak or strong illumination. The hypocotyls of plants grown in shaded room cultures were found to be etiolated and markedly heliotropic.

The structure of the hypocotyl in this species resembles very closely

a   *b*
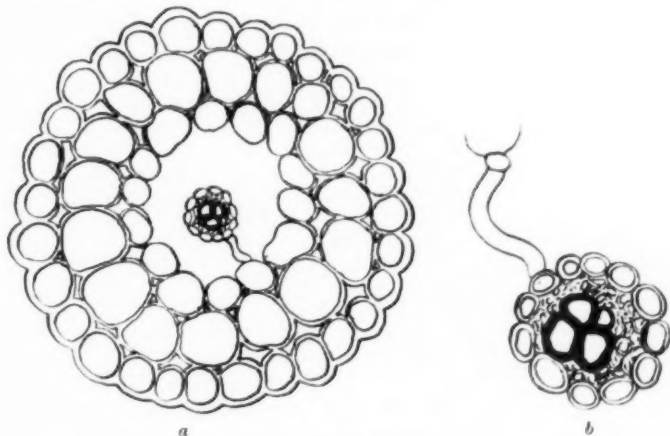
FIG. 17.

that described by Bruchmann for *S. Preissiana* (5). The cylindrical monarch stele is suspended in a central cavity by elongated endodermal cells (fig. 17, *a*, *b*). The tracheides of the xylem are few in number, with the protoxylem excentric and not central as in most described species. The pericycle cells are usually thick-walled, and in old plants the walls of the elements lying within the pericycle are also thickened. The cortex has well-defined intercellular spaces, and in old plants both outer cortical cells and epidermis are strongly thickened. Chlorophyll is present in the aerial region.

Branching.—In most described species of *Selaginella* the apex of the hypocotyl forks at the level of the cotyledons or some little distance above them, giving rise to two equal or sub-equal divaricating branches lying in the plane at right angles to the cotyledonary plane. More detailed study

20

of *S. pumila* has shown that in this species we have a modification of the branching usual in the genus, resulting in the curious, tufted habit of old plants.   The first dichotomy, which occurs at the level of the cotyledons, gives rise to two branches differing strikingly in size and behaviour.   One of these branches grows erect, and may proceed directly to cone development without branching again or may give rise to one or more unequal dichotomies, each apparently lateral branch ending in a cone.   The second (delayed) fork resulting from the dichotomy of the stem apex develops into a very short, horizontal rhizome.   This rhizome, as the result of unequal dichotomies, also produces, alternately right and left, a series of branches which are of the same order as those of the apparent main axis. The branches of the rhizome grow erect in well-illuminated plants, and may themselves undergo unequal dichotomies (figs. 18–20).   Thus a well-developed and equally illuminated adult sporophyte consists of an apparent
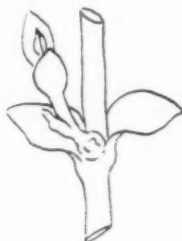
FIG. 18.   FIG. 19.   FIG. 20.

main axis, which is in reality the erect fork of the first dichotomy, with two fan-like systems of branches flanking it developed from the rhizome as indicated above (figs. 21, 22).   The rhizome produces, with each upright branch, a downward directed aerial " root."   Though branching occurs in all sporophytes, it is not unusual for the branches of the rhizome to be few in number and for some or all to remain rudimentary.   Thus the number of cones produced by the adult plant may vary within wide limits.   Among plants collected on the Stellenbosch flats in December of 1922 several were found with a single cone, while one exceptionally luxuriant growth had produced 160 cones.

As the spores germinate on or near the surface of the soil the rhizome is aerial to begin with, though usually not more than from 2 to 5 mm. above the ground.   Later, as the result of the action of wind and rain, it may become more or less completely buried in the soil.   Scale leaves occur on the rhizome and on the bases of the erect shoots developed from it.   These scale leaves are delicate in texture, with more or less conspicuously frayed

margins and a rudimentary or obsolete vascular supply. Intermediate conditions between typical scale and foliage leaves are met with.

Bruchmann has described the very similar method of branching which obtains in *S. Preissiana* (5). According to his account the erect branch of the first dichotomy in the Australian species always proceeds immediately to cone formation without branching again. The rhizome is described as creeping on the soil surface and giving off subterranean rhizophores below. It is probable that the study of additional material may show that these conditions are only occasional, as in *S. pumila*, and not of constant occurrence. Bruchmann (4) has also studied the method of branching in *S. Lyallii*, Spring, a handsome perennial species of *Selaginella* which is a native of Madagascar, but has been in cultivation for over half a century. This plant belongs to the sub-genus *Heterophyllum* of Hieronymus. The four-ranked leaves on the vertical stems are of equal size, but anisophylly
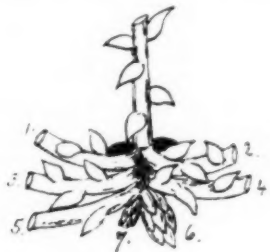
Fig. 21.   Fig. 22.

occurs exclusively on the upper frond-like branch systems. The adult plant possesses an elongated, subterranean rhizome, and reproduces vegetatively by the formation of new rhizomes from the tips of the leafy branches. Except for the fact that the rhizomes are elongated and perennial, they do not differ essentially from the contracted and short-lived rhizome formed from the delayed fork of the first dichotomy in *S. pumila* and *S. Preissiana*. An excellent figure of *S. Lyallii* is given by Hieronymus (17).

Systematic Position of S. pumila, and comparison with Allied Species.—Of the 700 or more known species of *Selaginella* only about 10 per cent. are isophyllous. The majority of these, according to Goebel, grow in dryer and better illuminated spots than the dorsiventral (15). Hieronymus (17), in his account of the *Selaginellaceae*, subdivides the sub-genus *Homoeophyllum* into two sections, *Cylindrostachyae* and *Tetragonostachyae*, based upon the arrangement of the sporophylls. The latter section, in which the sporophylls are arranged in four vertical rows, he subdivides further into three groups : 1, the group of *S. pumila*, in which the foliage leaves are often

decussate below but spiral above ; 2, the group of *S. uliginosa* and *S. Preis-siana*, with four-ranked foliage leaves ; and 3, the group of *S. rupestris*, with foliage leaves mostly in complex spirals. *S. bryoides*, which is merely a shade form of *S. pumila*, is the only other species placed by Hieronymus in group 1. Since it has been shown (11) that the leaves in *S. pumila* are really arranged throughout the entire plant in four orthostichies, there is no valid reason for separating this species from group 2, and so obscuring the close relationship which exists between *S. pumila* and *S. Preissiana*.

According to Hieronymus (17), *S. Preissiana* occurs in West Australia, Victoria, and Tasmania. Campbell, in a description of a recent visit to New South Wales, mentions that this species grows in abundance in the Blue Mountains (10).

Bruchmann, in 1910, published a short account of *S. Preissiana*, which is incomplete in several respects. An attempt has been made to secure living spores of this species as well as well-fixed material, for it is felt that a detailed comparison of the Australian and South African species would be of value. An examination of a small quantity of alcohol material from Australia has disclosed several features, not mentioned by Bruchmann, which agree closely with *S. pumila*. Some of the more striking points of resemblance between the two species are as follows :—

1. Length of time occupied by the life-cycle. Both are annuals.

2. General habit and mode of branching.

3. Presence of an endophytic fungus in the roots, coupled with the absence of root hairs.

4. Small-celled meristem at apex of root and stem.*

5. Anatomy of hypocotyl.

6. Transfusion tissue flanking the vein proper in foliage leaf and sporophyll.

7. Arrangement of stomata. As far as could be made out from the material of *S. Preissiana* examined, the base of the foliage leaf is slightly enlarged and possesses a group of stomata suggestive of that which occurs in *S. pumila*.

8. Presence of projection at base of sporophyll. In *S. pumila* this projection is entire, in *S. Preissiana* two-lobed.

9. Sculpturing of megaspore wall and marked extension of exospore beyond spore apex.

10. Frequent irregularity in size of megaspores and microspores of a tetrad.

* Lang, in a short abstract of Bruchmann's paper on *S. Preissiana* published in the Bot. Gaz. for 1910, writes : " Growth is by means of a single polyhedral apical cell." Bruchmann (5), however, states, " Da dem Scheitel der Sprosse dieser Pflanze eine Scheitelzelle fehlt, so entbehrt diese auch der Wurzelscheitel bei seinem Aufbau."

Bruchmann (5) states that rhizoidal protuberances were found in the female prothallus still associated with young plants of *S. Preissiana*. No rhizoids have been seen in any prothallus of *S. pumila*. Bruchmann mentions that a diaphragm is absent from the prothallus of *S. Preissiana*, but he makes no reference to the extent of tissue development in the spore cavity. In *S. pumila* the storage region of the megaspore remains non-septate throughout life. The thickening of the lower walls of the apical prothallus was found to vary, occasionally forming a distinct diaphragm, though the diaphragm was never as thick as that formed regularly in *S. Kraussiana*. In the material of *S. Preissiana* examined the cortical cavity, which is such a conspicuous feature of the root of *S. pumila*, appeared to be wanting or only poorly developed.

S. uliginosa is very different in general habit from *S. pumila* and *S. Preissiana*, though possessing the same four-ranked leaf arrangement. It is a perennial plant with horizontal, subterranean rhizomes and erect, leafy stems reaching the height of 14 cm. or more. Herbarium specimens collected by the writer on sandy flats near Long Bay, Sydney, Australia, during the summer of 1920 have been examined and found to possess several interesting features apparently hitherto unrecorded.* The roots, like those of *S. pumila* and *S. Preissiana*, contain an endophytic fungus. The bases of the oppositely placed leaves are conspicuously decurrent ; indeed the greater part of the surface tissues of the shoot axis are of foliar origin, thus supporting the " leaf skin theory " of Saunders (21). Stomata occur on the entire aligular surface, including the decurrent bases. The bands of reticulate transfusion tracheides flanking the leaf-vein, which are so striking a feature of the foliage leaf and sporophyll in *S. pumila* and *S. Preissiana*, are remarkably well developed in *S. uliginosa*. They do not accompany the leaf-trace in its oblique course through the cortex to the stele, but run down approximately parallel with the stem surface some distance below the insertion of the ligule. In transverse sections through the stem these tracheides may be seen in the outer cortex. It is possible that the layer of tissue containing them should, like the epidermis, be considered as of foliar rather than axial origin. Scale leaves which occur on the rhizome and on the subterranean parts of the erect axes show a very rudimentary bundle, which is confined to the base of the lamina and is accompanied by transfusion tracheides. Transitions occur between typical scale and typical foliage leaves.

The sporophyll possesses a particularly well-marked dorsal extension

* Since writing the above I have seen in Nature, Sept. 22, 1923, a brief abstract of a paper by Jessie K. Stele on " The Anatomical Features of the Mature Sporophyte of *S. uliginosa* " (read on July 25 at the Linnæan Soc. of N.S.W.). Miss Stele considers the species to be primitive, and refers to the frequent occurrence of a Selago condition.

which, like the similar structure in *S. pumila* and *S. Preissiana*, serves to protect the upper part of the sporangium lying immediately below. The cone apex may continue to grow and produce vegetative leaves above the reproductive area, a condition which Bower and others consider primitive. The transition from normal sporophylls to ordinary foliage leaves is a gradual one. This condition has not been found in either *S. pumila* or *S. Preissiana*, though in *S. pumila* a sporangium is occasionally found below the limit of the cone proper (12).

Plasticity of S. pumila.—Attention has already been drawn to the fact that the general habit of the sporophyte of *S. pumila* is profoundly modified by environment, especially by the conditions of illumination to which the young plant is exposed. The hypocotyls of sporelings which were

Fig. 23.

allowed to develop in the diffuse light at the back of the laboratory showed an inclination of about 45° towards the lighted window. Fig. 23 shows the marked heliotropic curvature of a young etiolated plant which had grown for several months under similar conditions. In nature two more or less distinct types may be recognised, a " flats type " found in exposed places where the plants are intensely and evenly illuminated, and a " hillside type " found usually in the shade and often subject to unequal illumination. The former is characterised by erect branches, lanceolate leaves, and compact erect sporophylls ; while the latter is more spreading in habit, with larger ovate leaves and recurved sporophylls. The characters of these types often overlap, and it is possible by changing the environment to cause the one type to pass into the other (fig. 24 ; Part I, fig. 1). A brief reference was made in Part I to the occurrence of dorsiventrality and anisophylly in the species. Since the publication of that paper numbers of specimens

Fig. 24
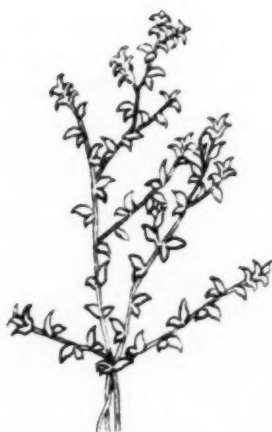
Fig. 25.

Fig. 26.

showing this condition have been noted. In every instance the shift of the leaf-bases and the frequent inequality in the size of the ventral and lateral leaves had apparently been conditioned by one-sided illumination. The anisophylly differs from that usual in the genus in that the leaves of the two ventral rows, instead of being flattened against the stem with the under surfaces illuminated, are so placed that the morphologically upper surfaces are directed to the light (figs. 25, 26).

Morphology of positively Geotropic Organs developed from Rhizome.—The question of the morphological status of the rhizophore will probably only be satisfactorily settled after an exhaustive comparative study has been made of the various " growth forms " included in the genus. From a study of *S. pumila* alone the writer is inclined to consider the downward directed organs arising from the rhizome as of the nature of roots in spite of their endogenous origin. The similarity in structure of the aerial and subterranean regions has already been noted (11). Bruchmann (5) refers to the corresponding organs developed from the rhizome of *S. Preissiana* as rhizophores ; but he goes still further and maintains that throughout the genus roots never arise directly from the stem but always from a rhizophore. He does not even recognise the presence of a primary root in the embryo. Worsdell (27), in his discussion of the rhizophore of *Selaginella*, writes as follows :—" Bruchmann's investigations of seedlings of *Selaginella* show that Pfeffer, Campbell, Velenovsky and others are mistaken in supposing that a primary root is present at all in this genus ; Velenovsky figures seedlings of *S. pumila* and *S. Preissiana* in which the primary root, according to his account, has arisen endogenously from the hypocotyl, which seems to indicate that the extreme basal portion of that organ is, in reality, a rhizophore, which has, like the ' protocorm ' in certain Lycopodiums, almost reached its vanishing-point." Velenovsky's work has, unfortunately, not been available for reference.

Characters in S. pumila which are possibly to be looked upon as Primitive.

1. *Isophylly.*—It is natural to consider this condition as relatively more primitive than anisophylly. It should, however, be remembered that in *S. pumila* the phyllotaxy appears to have been derived from an opposite and decussate condition such as occurs in *S. uliginosa.* The direct ancestors of our modern *Selaginellas* may be represented by the herbaceous *Selaginellites* of the Palaeozoic rather than by the tree-like Lycopods of the same age. Some, at least, of the former are known to have been anisophyllous. It is possible that the isophylly of *S. pumila* is secondary and not primitive, and that the anisophylly resulting from

one-sided illumination is to be looked upon as reversion to an originally anisophyllous condition.

2. *Enlarged Leaf-Base.*—The resemblance of this structure to the familiar leaf-cushion of *Lepidodendron*, etc., had already been pointed out (11).

3. *Transfusion Tracheides in the Leaf.*—A sheath of scalariform or spiral tracheides was known to have surrounded the bundle of the vegetative leaf in *Lepidodendron* and *Sigillaria* (22, 23). The flanking bands of tracheides in the leaf of such species of *Selaginella* as *S. pumila*, *S. Preissiana*, *S. uliginosa*, and *S. Lyallii* may, perhaps, be interpreted as traces of this ancient tissue. On the other hand, it is possible that these tracheides may have arisen comparatively recently in response to physiological needs. In *S. pumila* they are absent from the cotyledons and first foliage leaves. Their function may be that of water storage, though from a consideration of the distribution of stomata, etc., it seems likely that they are more concerned with the movement than the storage of water. The development of secondary tracheides about the base of the ligule of the foliage leaf is known to occur regularly in investigated species of *Selaginella* (16, 20). The bands of transfusion tracheides of the lamina of *S. pumila* link up with these reticulate tracheides of the ligule base and should, perhaps, be considered as a further extension of them.

4. *Monostely.*—Although *S. pumila* possesses a single stele, the structure does not resemble that of the radial and presumably primitive stele of *S. spinulosa*, but approximates more closely to the ribbon-like stele of the simpler dorsiventral species.

5. *Presence of Air Cavity in Root Cortex.*—A comparison with the root of *Isoetes* and *Stigmaria* has already been made (11). This feature may be the direct result of the marsh conditions under which the sporophytes usually develop for at least a part of their existence.

6. *Small-celled Tissue at Apex of Root and Stem.*—This condition is often considered as derived from a more primitive growing-point with a single apical cell. Bower (1), however, points out that in the ancient genus *Lycopodium* the tissues are not referable to a single initial cell, and also that in *S. spinulosa*, generally considered as a relatively primitive type of the genus, a small-celled meristem is present in stem and root. In the present state of our knowledge it is hardly possible to come to any definite conclusion as to the relative antiquity of the two conditions.

7. *Presence of downward directed Flap to Sporophyll.*—Lang and others have pointed out the resemblance of the complex sporophylls of *Lycopodium cernuum*, etc., to the extinct Spencerites (23). In arranging the sporophylls of *Selaginella* in a series according to the degree of complexity exhibited, one is inclined to consider the most highly specialised as relatively primitive

and the simpler as due to reduction, though it is, of course, possible to read the series differently.   There is no doubt that such extensions to the base of the sporophylls as occur in *S. pumila, S. Preissiana, S. uliginosa, S. rupestris*, etc., afford protection to the sporangia in species which produce cones in more or less exposed situations and under dry climatic conditions.

8. *Projection of Spore Coat at Apex of Megaspore.*—The megaspore of *S. pumila*, with its apical projection, is so suggestive of the megaspore of *Lepidostrobus oldhamius* that the resemblance is worth noting (23).

9. Occasional presence of a sporangium below the limits of the cone proper.

Characters which are probably to be considered as Advanced.

1. *Maturing of a Single Spore Tetrad in the Megasporangium.*—It is well known that certain species of *Selaginella* frequently mature more than four megaspores in a megasporangium, a condition which is looked upon as relatively primitive.   The palaeozoic *Selaginellites* also matured more than four megaspores (23, 24).

2. *Frequent inequality of Spores of Tetrad leading often to a complete Abortion of from one to three Spores.*—It should be noted that this condition occurs in microsporangia as well as in megasporangia (12).

3. *Limited development of Prothallial Tissue in the Megaspore.*—The absence of " storage endosperm " may be the result of the shortening of the life-cycle.

Characters which, whether interpreted as relatively Primitive or Advanced, appear to be definitely associated with the Environment of the Plant.

(Note strong and equal illumination to which the sporophytes are, as a rule, exposed during the later stages of development; moist yet variable condition of the soil during the greater part of the growth of the plant, and necessity of completing the entire life-cycle in nine or ten months.)

1. *Peculiar Method of Branching leading to Tufted Habit.*

2. *Isophylly.*

3. *Air-cavity in Root.*

4. *Absence of Root Hairs.*—This is undoubtedly connected with presence of endophytic fungus.   Both may possibly be due to marsh habit of young plants.

5. *Transfusion Tracheides in Leaf.*

6. *Dorsal Flap of Sporophylls.*

7. *Curtain-like Projection of Megaspore Membrane.*—This structure appears to afford some protection to the prothallus and young embryo.

8. *The Shedding of the Spores before the Formation of Prothallus Tissue.*— By the time the spores are mature the ground has usually dried out and the annual flora of the flats and adjacent hills is seeding. The dormancy of the spores during the months of drought and the capacity of spores, prothalli, and young embryos to endure prolonged and intermittent drying are also to be connected with environmental conditions. Probably the failure of " storage endosperm " to develop is likewise connected with the shortening of the life-cycle, while the absence of a suspensor in the embryo is possibly conditioned again by the absence of storage endosperm.

The absence of rhizoids may also be connected with the limited development of prothallial tissue. Bruchmann reports the occurrence of rhizoids and rhizoidal protuberances in all species of *Selaginella* examined by him. He suggests that the protuberance may serve to prevent the retreat of the prothallus into the spore coat when suffering from temporary loss of moisture. In *S. pumila* the moisture conditions of the habitat during the germination of the spores are so variable that the prothallus must frequently retreat within the spore coat for protection.

Conclusion.—*S. pumila* may be considered as a very plastic species, showing marked adaptation to its environment and possessing a number of characters which are suggestive of ancient Lycopods in addition to others which are probably of recent origin. It has many striking points of resemblance to the Australian species *S. Preissiana*, with which it appears to be closely allied.

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EXPLANATION OF FIGURES.

Fig. 1. Young sporelings, enlarged.

Fig. 2. Longitudinal section through apex of megaspore with young embryo in venter of archegonium.

Fig. 3. Longitudinal section through archegonium, showing thickening of neck cells and venter.

Fig. 4. Slightly oblique, longitudinal section through young embryo.

Figs. 5–9. Consecutive transverse sections passing through a fertilised archegonium.

Fig. 5. Transverse section through apex of megaspore, showing upper tier of neck cells and outer wall of six prothallus cells.

Fig. 6. Transverse section through apex of megaspore, showing lower tier of open archegonial neck embedded in prothallus.

Fig. 7. Transverse section through apex of megaspore, showing embryo embedded in prothallus.

Figs. 8 and 9. Transverse sections through young embryo.

Fig. 10. Longitudinal section through older embryo after organisation of stem tip and cotyledons.

Fig. 11. Older sporeling still surrounded by membrane of prothallus cells.

Fig. 12. Sporeling freed from spore coats.

Fig. 13. Lower part of axis of sporeling partly covered by membrane of prothallus cells and outgrowth of exospore.

Fig. 14. Transverse section through axis and foot of sporeling, showing large haustorial cells projecting into spore cavity.

Fig. 15. Cotyledons of sporeling before separation of laminae.

Fig. 16. Cotyledons (seen from above) after the laminae have unfolded.

Fig. 17*a*. Transverse section through hypocotyl.

Fig. 17*b*. Transverse section through stele of hypocotyl.

Fig. 18. Sporeling, showing first dichotomy.

Fig. 19. Sporeling, showing first erect branch of rhizome.

Fig. 20. Sporeling, showing first and second erect branches of rhizome and two aerial "roots."

Fig. 21. Base of adult plant seen from above.

Fig. 22. Section through base of adult plant in the plane of the cotyledons.

Fig. 23. Etiolated plant, showing heliotropic curvature.

Fig. 24. Specimen showing effect of changed environment on young cones.

Fig. 25. Plant from hillside, showing effect of one-sided illumination.

Fig. 26. Anisophylly, resulting from one-sided illumination.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE FRESHWATER ALGAE OF AFRICA.

4. *Freshwater and Subaerial Algae from Natal.**

By F. E. Fritsch

AND

Florence Rich.

(With 31 figures in the Text.)

A. Introductory Remarks.

As far as we are aware, no previous account of any kind regarding the freshwater and subaerial algal flora of Natal has been published, and the present investigation of one hundred different samples thus affords the first available data on this point. We may consider ourselves especially fortunate that so competent a scientist as Professor J. W. Bews, D.Sc., who has added so materially to the knowledge of the ecology of the South African flora, undertook the collection of the majority of these samples. The latter have been gathered from very diverse parts of the country and, whilst a large number come from the neighbourhood of Maritzburg or from the Drakensberg region, others have been collected from places so far apart as Greytown, Vryheid, Newcastle, etc. Moreover, from several of these localities the samples appear to constitute a fairly representative series embodying a diversity of algal habitats, and we may probably take it that at these points no frequently recurring type of freshwater or subaerial locality has escaped the eye of the collector. All of Professor Bews' collections were made between March and September of 1915, *i.e.* during the dry period when the gathering of samples is presumably most feasible.

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None of the samples come from sea-level, the lowest altitude at which any of the collections were made being Maritzburg and neighbourhood on the borders of the South African plateau between the 2000 and 3000 ft. level.

Regarding the collections as fairly characteristic of the regions from which they were gathered, one is immediately struck by the paucity of species and genera (*cf.* the table below). The groups best represented are the Desmidiaceae, Cyanophyceae, and Diatomaceae (Bacillariales), the last-named being probably far more abundant, since as a general rule we have

Table showing Numbers of Species and Genera belonging to the Different Groups.

	Total Sp.	New Sp.	Total Genera.	New Genera.	New Varieties.	New Records.
Protococcales	8	..	6	..	1	6
Ulotrichales	8	2	5	1	..	3
Chaetophorales	2	..	1	..	..	..
Oedogoniales	4	..	1	..	..	4
Siphonales	3	1	1	..	..	2
Desmidiaceae	61	3	12	..	7	41
Zygnemaceae	6	..	4	..	1	4
Heterokontae	3	..	3	..	..	1
Cyanophyceae	49	6	23	..	3	33
Florideae	2	..	2	..	..	1
Diatomaceae	78	2	19	..	3	50
Flagellata	4	..	4	..	..	..
Totals	228	14	81	1	15	145

only determined the Diatoms occurring more frequently in the samples. Of the three commoner groups the only one that can be said to play a relatively conspicuous rôle is that of the Cyanophyceae, and we may associate this in part with the subtropical climate * of the lower regions of Natal and in part with the abundant occurrence of lithophytes in the moist mountain zones.† ' If we leave out of account the Drakensberg samples, which are mainly subaerial, it is noticeable in how large a number of collections blue-green algae are practically the only or at least the dominant forms (*cf.* samples 216, 217, 218, 220, 222, 224, 225, 232, 247, 248, 252, 254, 260, 263, 266, 267, 268, 273, 275, 280, 283, 284, 286, pp. 302–307).

As regards the Desmidiaceae the numbers shown in the table give no clear indication of the relatively poor representation of this group. The only sample which could be said to be at all rich in Desmids, and which also harboured several of the scanty Protococcales (*cf.* however also No.

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* *Cf.* Fritsch, in Ann. of Bot., xxi, 1907, p. 238 *et seq.*

† Fritsch, in Journ. of Ecology, x, 1922, p. 232.

230), was No. 246 from a quiet pool in a stream at Cedara, but even here there does not seem to have been any great abundance of individuals. Nevertheless one can fairly say that, if sample 246 had not been collected, one would have been compelled to describe the region under discussion as one showing the greatest paucity of Desmids * among any that have become known with the exception of the Antarctic. If we exclude sample 246, there are only eight genera and thirty-three species of Desmids in the entire collection. It is noticeable that the few other samples in which Desmids occurred in any numbers, likewise often came from quiet pools in streams (see Nos. 235, 239, 242, 244, 253, 261, 262, 272, 282). The scantiness of Desmids and Protococcales was noted also in the collections from the Kentani District of Cape Colony,† and in either case no adequate explanation is at present available.

Quite a number of the collections have been gathered from flowing water, and harbour a representative series of forms very analogous to those to be encountered in similar habitats in Europe. The following is an abbreviated list :—

> Cladophora crispata.
> Stigeoclonium tenue.
> Oedogonium fragile, etc.
> Phormidium autumnale.
>   „   retzii.
> · Chantransia chalybea.
> Batrachospermum huillense.
> Oncobyrsa rivularis.

Other samples contained soil-inhabiting Algae from various situations, identical with or parallel to the forms found in such localities in other parts of the world, *e.g.* :—

> Hormidium flaccidum.
> Vaucheria sessilis.
>   „   hamata.
>   „   pseudomonoica n. sp.
> Botrydium granulatum.
> Microcoleus vaginatus.
>   „   annulatus n. sp.
> Nostoc humifusum.
>   „   ellipsoideum.
> Gloeocapsa spp.
> Navicula borealis.

* *Cf.* also Fritsch and Stephens, in Trans. Roy. Soc. South Africa, ix, 1921, p. 2.
† Fritsch and Stephens, *loc. cit.*, p. 2.

Particular interest attaches to the collections of subaerial forms from the Drakensberg region (samples 292, 294, 295, 298, 299, 301, 302, 303, 305, 306, 307, 308, *cf.* pp. 308, 309). " The first plants to invade the bare rock faces are various blue-green algae. The associations of these cover enormous areas of the cliffs, especially the cave-sandstone cliffs, and are strikingly apparent from a distance as longitudinal black strips.* By the invasion of fungi, they are changed into lichen associations, giving a variety of colours to the rock face—black, green, yellow, red, grey, or white—but the lichen associations, though probably much more numerous in point of species, are not of such importance ecologically, nor, as far as the writer's observation goes, nearly so extensive as the associations of Cyanophyceae," † Professor Bews then proceeds to cite from the letters of the first-named author of the present communication with respect to the algal composition of this growth (*cf.* below), which samples he continues (*loc. cit.*, p. 554) " were taken from the cliffs in the Drakensberg at points many miles apart, so that it will be seen that the succession indicated is a very extensive one, and probably it extends throughout the whole range. During the dry weather the algal covering dries up and peels from the rock in small flakes, but it does not disappear to any great extent or leave the rock again bare." The conditions which favour this luxuriant growth of blue-green lithophytes are indicated on p. 524 of the same communication, where Professor Bews says : " During the winter dry season, when anticyclonic conditions prevail over Natal, the mountains remain for the most part clear of fog. Cold mists deposit a certain amount of moisture in the valleys, owing to the inversion of temperatures already described. In the summer rainy season, mists prevail on the mountains. The mist-belt of each mountain varies somewhat in position, the amount of mist usually, however, increasing with altitude, the base of the mountain being comparatively free from it. The rainfall behaves similarly."

With regard to the actual colonisers and the stages in colonisation, most of the essential facts have already been given in the papers of Professor Bews as citations from the letters of the first of us.‡ We repeat these facts here with such emendations as the present paper has suggested. The samples of lithophytes sent by Professor Bews (Nos. 104, 105, 113) and to which his remarks above quoted refer, contained in two out of the three cases a composite growth of Cyanophyceae consisting in the main of four forms, viz. *Stigonema hormoides*, Bornet et Flahault var. *africana* n. var.

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* *Cf.* also Welwitsch, in Journ. of Travel and Nat. Hist., i, 1868 ; McLean, in Journ. of Ecology, vii, 1919, p. 7.

† Bews, " The Plant Ecology of the Drakensberg Range," Annals Natal Museum, iii, 1917, p. 553.

‡ See also Bews, in Journ. of Ecology, iv, 1916, p. 132.

(*S. hormoides* forma in Bews, *loc. cit.*, p. 554), *S. informe*, Kuetz., *Schizothrix epiphytica* n. sp., and *Gloeocapsa sanguinea*, Kuetz. These appear to form an intimate association or consortium*, in which the *Gloeocapsa* is the first arrival, the two species of *Stigonema* developing upon the substratum thus afforded. In the material sent a good deal of the *Gloeocapsa* looked moribund, although a considerable number of fresh and vigorous colonies were to be found among the tangle of *Stigonema*. Of the two species of *Stigonema*, *S. hormoides* var. *africana* usually had the upper hand and was the more abundant, *S. informe* suffering largely from the growth of *Schizothrix epiphytica* n. sp. This, which would appear to have been the most recent arrival, almost completely enshrouded some of the threads of the two species of *Stigonema* with its red coiling filaments (*cf.* fig. 22, *A*, p. 362). Particularly between the upright branches of *Stigonema informe* and the *Schizothrix* a struggle for supremacy was going on, analogous to that described by Fritsch † for similar stages in colonisation in Ceylon.

The foregoing paragraph contains essentially a description of Professor Bews' sample 104 (not included in the present series), from the Goodoo Pass (6000 ft.). Sample 105 (No. 295 of the present paper) from the Tugela Gorge (7000 ft.) shows that the same type of growth occurs also in other parts of the Drakensberg range, although evidently with a somewhat different balance between the competing forms. In this, too, a fifth form, *Calothrix parietina* (Naeg.), Thuret var. *africana* n. var., plays a prominent part, and judging by sample 113 (No. 302 of the present paper) this becomes the dominant form in some parts of the Goodoo Pass.

On moister portions of the rock-face (samples 298, 299) we have encountered *Scytonema splendens* n. sp., again evidently colonising a substratum formed by species of *Gloeocapsa*, and accompanied by species of *Epithemia* and *Rhopalodia* in some abundance. Samples have also been collected from the rock-flushes, about which Professor Bews says : ‡ "The substratum is here continually, or almost continually, wet, like it is near minor waterfalls, etc., where the water trickles over the rock-face. Blue-green algae are again found in places where there is continual drip, particularly in sunny situations." The samples in question are 292, 295, 305, 306, 307, 308 (*cf.* pp. 308, 309), which are composed in the main either of green forms (*Cladophora crispata*, *Spirogyra* spp., *Oedogonium* spp.), accompanied by species of *Epithemia* and other Diatoms, or of an essentially blue-green growth (*Nostoc* spp., *Gloeocapsa* spp., *Schizothrix fuscescens* forma, *Calothrix braunii* forma, *Scytonema myochrous* forma) with an often considerable admixture of Protococcales, Desmids, and Diatoms.

* *Cf.* Fritsch, New Phytologist, v, 1906, p. 158.

† Proc. Roy. Soc., B, lxxix, 1907, p. 213, fig. 2 ; Geogr. Journ., 1907, p. 540, fig. 1.

‡ *Loc. cit.*, p. 555.

Amongst points of special systematic interest may be noted the discovery of a new genus of Ulotrichaceae (*Pearsoniella* n. gen.), the discovery of *Oedogonium rigidum*, Hirn, hitherto only recorded from South America, and the extension of the ranges of *Cylindrospermum alatosporum*, Fritsch and *Batrachospermum huillense*, Welwitsch MS.

B. Enumeration of the Samples.

The following list of samples serves as a key to the collections, the numbers of the samples only being cited in the subsequent systematic portion. With the exception of samples 468–470 which were collected by G. C. Nel in January of 1921, all the samples were gathered by Professor J. W. Bews during the year 1915. The first number cited under each sample refers to the general collection of South African Algae (*cf.* footnote on p. 297), that following in brackets being Professor Bews' own number.

214 (1). Surface film lining the inside of an old wooden water-tub, Maritzburg, March 17. (*Pearsoniella variabilis* n. gen. et sp., *Stigeoclonium falklandicum*).

215 (2). On clay bank under bridge on Durban Road, near Maritzburg, March 17. (*Ulothrix aequalis.*)

216 (3). On mud in ditch by side of Durban Road, near Maritzburg, March 17. (*Oscillatoria geminata, O. tenuis.*)

217 (4). Stagnant water in drain entering Umsindusi, near Maritzburg, March 18. (*Phormidium tenue, Oscillatoria formosa.*)

218 (5). Stagnant water from a drain, Maritzburg, March 18. (*Oscillatoria princeps, Euglena* sp., *Nitzschia* sp.)

219 (6). On thin layer of mud attached to submerged rocks in Umsindusi River, near Maritzburg, March 18. (*Spirogyra* sp., *Lyngbya aerugineocaerulea, Synedra ulna* var. *aequalis, Navicula tenella, N. rhynchocephala, N. cincta, Cymbella ventricosa* var. *obtusa, Nitzschia sigmoidea, N. inconspicua,* etc.)

220 (7). Submerged tree-trunk in Umsindusi River, near Maritzburg, March 18. (*Oscillatoria limosa, Closterium* sp., rare Diatoms.)

221 (8). On clay bank near Umsindusi River, Maritzburg, March 18. (*Ulothrix oscillarina, U. aequalis*, Moss protonema.)

222 (10). Semi-gelatinous film on tops of flower-pots in greenhouse of Natal University College, March 19. (*Phormidium tenue, Oscillatoria brevis, Navicula kotschyi, Nitzschia communis.*)

223 (11). On bark of *Pinus*, Maritzburg, March 20. (Mosses with fragments of *Hormidium* sp.)

224 (12). On matted roots of *Papyrus* in pond in Botanic Gardens, Maritzburg, March 20. (*Cylindrospermum alatosporum.*)

225 (13). Covering stones in pond in Botanic Gardens, Maritzburg, March 20. (*Lyngbya versicolor.*)

226 (14). Top of flower-pot in greenhouse in Botanic Gardens, Maritzburg, March 20. (*Calothrix* sp.)

227 (15). On outside of flower-pot in greenhouse of Botanic Gardens, Maritzburg, March 20. (*Calothrix* sp.)

228 (16). On surface of a dry mud-wall, Maritzburg, March 22. (No Algae recognisable in the sample.)

229 (18). Free-floating in mountain-stream at Vryheid, altitude 4000 ft., March 24. (*Zygnema pectinatum*, *Spirogyra* sp., *Scytonema bewsii* n. sp.)

230 (19). Reddish-green surface-scum, disappearing after a few days, from pond at Maritzburg, March 26. (*Scenedesmus quadricauda* var. *africana* n. var., *Pediastrum tetras*, *Euglena* sp., *Chlamydomonas* sp.)

231 (21). Covering damp bricks in greenhouse, Maritzburg, March 26. (*Chroococcus cohaerens*, *Gloeocapsa caldariorum*, *Homoeothrix aequalis* n. sp., *Achnanthes microcephala*, *Rhopalodia gibberula*.)

232 (22). Gelatinous clumps on moist earth in greenhouse, Maritzburg, March 26. (*Nostoc humifusum*, *Lyngbya mucicola*, *Gloeocapsa caldariorum*, *Rhopalodia gibberula*.)

233 (24). On frond of *Hydrostachys natalensis* in Umsindusi River, Maritzburg, March 28. (*Synedra vitrea*, *Nitzschia palea*.)

234 (25). Among rocks in bed of Umsindusi, Maritzburg, March 28. (Decomposed freshwater sponge, *Phacus* sp., *Chlamydomonas* sp. ?)

235 (26). On bed of Umsindusi, Maritzburg, March 28. (*Plectonema tomasinianum* forma, *Spirogyra* sp., *Closterium moniliferum*, *Synedra vitrea*, *Navicula cincta*, *N. tenella*, etc., *Gomphonema parvulum*, etc., *Nitzschia hantzschiaeformis* n. sp. and var. *constricta* n. var., *N. sigmoidea*.)

236 (27). On surface of Liverwort from Town Bush Valley, near Maritzburg, March 31. (*Melosira roeseana*, *Synedra vitrea*, *Achnanthes inflata*, *Stauroneis anceps* var. *lata* n. var., *Epithemia zebra* var. *porcellus*.)

237 (28). Free-floating in old quarry at Newcastle, altitude 4000 ft., April 5. (*Spirogyra decimina* forma *tropica*.)

238 (29). Among roots of water-plants in mountain-stream, near Newcastle, April 6. (*Nitella* with epiphytic *Oedogonium* sp., *Synedra longissima*, *S. vitrea*, *Nitzschia communis*, *Eunotia pectinalis*.)

239 (30). In mountain-streamlet, Newcastle, April 6. (*Mougeotia* sp., *Spirogyra inflata*, *Cosmarium laeve*, *C. trilobulatum* forma, *Synedra amphirhynchus* var. *fragilariaeformis* n. var., *S. delicatissima*, *Navicula vulgaris*, *N. mesolepta* var. *africana* n. var., *Cymbella ventricosa* var. *obtusa*, *Surirella apiculata*.)

240–241 (31–32). Mountain-stream, Newcastle, April 7. (*Batracho-*

spermum huillense, Oedogonium fragile, Ophiocytium cochleare, Spirogyra spp., *Closterium moniliferum, C. pritchardianum, C. lanceolatum.*)

242 (33). Mountain-stream, Newcastle, April 7. (*Mougeotia* sp., *Spirogyra* sp., *Netrium digitus, Cosmarium laeve, C. boeckii, C. pseudobroomei* var. *compressum* forma, *Synedra amphirhynchus* var. *fragilariaeformis* n. var., *S. delicatissima, Navicula vulgaris, N. mesolepta* var. *africana* n. var.)

243 (34). Gelatinous growth in boggy place on hillside, Newcastle, April 8. (*Tribonema bombycinum* forma *minor, Oedogonium* sp., *Chlamydomonas* sp., *Synedra amphirhynchus* var. *fragilariaeformis* n. var.)

244 (35). On mud from bottom of pool in mountain-stream, Newcastle, April 7. (*Closterium pritchardianum, C. littorale* var. *crassum, C. leibleinii* forma, *Cosmarium binum.*)

245 (37). Gelatinous clumps among mosses, half submerged in running water, Town Bush, Maritzburg, April 2. (*Nostoc* sp.)

246 (39). On rocks in quiet pool in stream, Cedara, April 18. (*Oedogonium rigidum, Zygnema* sp., *Hyalotheca dissiliens, Spirotaenia condensata, Netrium* spp., *Closterium parvulum, C. abruptum* forma, *C. navicula, C. pritchardianum, Pleurotaenium ehrenbergii* forma, *Euastrum brasiliense* formae, *E. elegans* var. *symmetricum* n. var., *E. incertum* n. sp., *Micrasterias bewsii* n. sp., *M. truncata* var. *africana* n. var., *M. denticulata, M. decemdentata, Cosmarium* spp. (especially *C. bewsii* n. sp., *C. binum, C. cucurbita* forma and var. *attenuatum, C. hammeri* forma, *C. javanicum* var. *profundoconstrictum* n. var., *C. laeve, C. lundellii* var. *corruptum, C. mansangense* var. *africanum* n. var., *C. margaritiferum* var. *exsertum* n. var., *C. pseudopyramidatum, C. tetragonum* var. *bipapillata, C. trachypleurum* var. *natalensis* n. var., *C. trilobulatum* forma), *Staurastrum alternans, S. sebaldi* var. *altum* forma, *S. trihedrale, Oocystis crassa* forma, *Scenedesmus bijugatus* var. *alternans, Ankistrodesmus falcatus, Microcystis aeruginosa, Scytonema mirabile, Calothrix* sp., *Eunotia arcus* var. *bidens, E. lunaris, E. uncinata, Navicula major, N. viridis* var. *elliptica, N. mesolepta* var. *africana* n. var., *Stauroneis phoenicenteron, Surirella biseriata.*)

247 (40). Attached to bed of stream in running water, near Cedara, April 14. (*Phormidium autumnale.*)

248 (41). Attached to rocks in bed of stream, near Cedara, April 1. (*Phormidium* sp.)

249 (42). Surface-scum from quiet pond in stream, near Durban Road, April 26. (*Synedra vitrea, Navicula bacilliformis, N. tenella, N. ambigua, N. acrosphaeria* var. *minor, Nitzschia sigmoidea, N. palea, Cymatopleura solea* var. *clavata, Surirella ovalis.*)

250 (43). In bed of stream, attached to rocks in running water, Polly Short's cutting, Maritzburg, April 24. (*Cladophora crispata.*)

251 (44). Same locality, etc. as 250. (*Spirogyra neglecta* forma, *Oedogonium* sp., *Synedra vitrea*.)

252 (45). Surface-scum from stagnant pool in stream at Scottsville, Maritzburg, May 2. (*Oscillatoria irrigua, O. tenuis, Phormidium valderianum* ?, *Spirulina major*.)

253 (58). On rocks in stream, Edendale, May 25. (*Oedogonium* sp., *Sirogonium sticticum* forma, *Netrium digitus, Micrasterias truncata* var. *africana* n. var., *Cosmarium pachydermum* var. *aethiopicum* forma, *C. gayanum* var. *rotundata* forma, *C. hammeri* forma, *Calothrix* sp., *Synedra longissima, Navicula divergens* var. *elliptica, Rhopalodia* spp., *Nitzschia tryblionella* var. *victoriae*.)

254 (59). On clumps of *Notoscyphus lutescens*, Hilton Road, Maritzburg, subaerial, May 25. (*Schizothrix* sp.)

255 (60). On dead leaves of *Typha capensis* in old quarry, Victoria Bridge, Maritzburg, moist, aerial, shaded, June 5. (*Schizomeris irregularis* n. sp., *Stigeoclonium* sp., *Oedogonium* sp., *Tribonema bombycinum* forma *minor, Closterium malinvernianum, C. subulatum, Trachelomonas hispida*.)

256 (62). Greyish-black ooze from mass of decaying *Typha* in old quarry, Victoria Bridge, Maritzburg, June 5. (*Closterium malinvernianum, C. subulatum, C. leibleinii, Trachelomonas hispida*.)

257 (63). In stagnant water in quarry at Victoria Bridge, Maritzburg, June 5. (*Ulothrix variabilis, Oedogonium* sp., *Tribonema bombycinum* forma *minor, Ophiocytium cochleare, Spirogyra* sp., *Closterium* spp., *Trachelomonas* spp.)

258 (64). Scum on submerged sand in Umsindusi River, Victoria Bridge, Maritzburg, June 5. (*Oscillatoria* sp., *Navicula elliptica, N. acrosphaeria* var. *minor, N. stauroptera* var. *interrupta, Gyrosigma acuminatum, Denticula tenuis, Nitzschia tryblionella* var. *victoriae, N. sigmoidea, N. sigma, N. clausii, Hantzschia amphioxys, Surirella linearis, S. splendida, Stenopterobia anceps*.)

259 (65). Gelatinous subaerial growth among mosses, The Knoll, Maritzburg, May 28. (*Collema* sp.)

260 (66). Gelatinous clumps on *Anthoceros*, Sweetwaters, Maritzburg, May 28. (*Nostoc ellipsosporum*.)

261 (67). Free-floating in quiet pool in stream, Chase Valley, Maritzburg, May 22. (*Spirogyra* sp., *Mougeotia* sp., *Closterium moniliferum, C. pritchardianum, C. navicula, C. lanceolatum, Oscillatoria limosa, O. tenuis, O. irrigua, Synedra vitrea, S. longissima, Navicula vulgaris, N. rhynchocephala, N. borealis, Gomphonema crassestriatum* n. sp., *G. parvulum, Nitzschia sigmoidea, N. palea, Hantzschia amphioxys, Surirella splendida, Trachelomonas volvocina, Lepocinclis ovum*.)

262 (68). In running water, mostly attached, Chase Valley, Maritzburg,

May 22.   (*Oedogonium* sp., *Mougeotia* sp., *Spirogyra neglecta* var. *pseudo-ternata* n. var., *Closterium subulatum, Cosmarium boeckii, C. gayanum* var. *rotundata* forma, *C. pseudobroomei* var. *compressum* forma, *Synedra ulna* var. *aequalis, S. vitrea, Navicula rhynchocephala, N. radiosa, N. acrosphaeria, Gomphonema* spp., *Cymbella ventricosa* var. *obtusa, Nitzschia sigmoidea, N. palea, Hantzschia amphioxys, Surirella angusta.*)

263 (69). Attached in stream below small waterfall, Chase Valley, Maritzburg, May 22.   (*Phormidium retzii.*)

264 (70). Scottsville, Maritzburg, very abundant, June 8.   (*Spirogyra longata.*)

265 (71). In stream at Scottsville, Maritzburg, June 8.   (*Nitella* with epiphytic *Oedogonium* sp., *Synedra longissima, Navicula elliptica, N. borealis, N. viridis* var. *elliptica, Epithemia argus.*)

266 (72). Bottom-scum in drain at Scottsville, June 8.   (*Spirogyra* sp., *Oscillatoria irrigua, Phormidium autumnale, Euglena* sp.)

267 (74). In stagnant water in stream at Scottsville, June 8.   (*Spirogyra* sp., *Oscillatoria irrigua, Synedra longissima, Navicula ambigua, N. rhynchocephala, Gyrosigma acuminatum, Nitzschia hungarica, N. sigmoidea, N. sigma, N. palea, Surirella ovalis, Stenopterobia anceps.*)

268 (75). In stagnant water, below Police Barracks, Scottsville, June 8.   (*Spirogyra* sp., *Oscillatoria irrigua, Euglena* sp.)

269 (76). Surface-scum on stagnant pool near Police Barracks, Maritzburg, June 8.   (*Mougeotia* sp., *Spirogyra* sp., *Pleurotaenium trabecula, Closterium leibleinii* forma, *Cosmarium boeckii, Gyrosigma acuminatum, Cymbella ventricosa* var. *obtusa, Navicula ambigua, Rhopalodia gibba, Nitzschia sigmoidea, N. palea, Surirella ovalis.*)

270 (77). In stream at Scottsville, very common, June 8.   (*Spirogyra longata, Spirulina major.*)

271 (79). Black deposit on stony bed of stream, Star and Garter, 5 miles from Maritzburg, June 12.   (*Spirogyra* sp., disorganised.)

272 (80). In running water, Star and Garter, near Maritzburg, June 12. (*Nitella* with epiphytic *Oedogonium* sp., *Spirogyra* sp., *Zygnema* sp., *Pleurotaenium ovatum* forma, *P. subcoronulatum* formae, *P. trabecula, Closterium kuetzingii, C. lineatum, Cosmarium constrictum, C. pseudobroomei* var. *compressum* forma, *Oscillatoria irrigua, O. tenuis, Cyclotella meneghiniana, Synedra longissima* and var. *acicularis, Navicula zellensis, N. major, N. viridis* var. *elliptica, N. amphirhynchus, Stauroneis phoenicenteron, Nitzschia stagnorum, N. sigmoidea, N. sigma, Surirella splendida.*)

273 (81). Among mosses on rocks, Overwood, Polela, May 6.   (*Nostoc* sp., *Lyngbya aerugineo-coerulea, Cosmarium holmiense, Melosira roeseana, Synedra longissima* var. *acicularis, Achnanthes inflata, Navicula borealis, Hantzschia amphioxys.*)

274 (82). Among mosses in a stream, Overwood, Polela, June 12. (*Nostoc* sp., *Oedogonium* sp.)

275 (83). Black patches, floating on the surface of an irrigation trench, Edendale, June 24. (*Oscillatoria irrigua, Merismopedia glauca, Closterium pritchardianum, Synedra vitrea, Eunotia pectinalis, Gomphonema parvulum, Achnanthes inflata, Navicula interrupta* forma, *N. major, Nitzschia* spp., *Surirella splendida.*)

276 (84). Greyish-green scum on surface of irrigation ditch, mixed with leaves, Edendale, June 24. (*Pearsoniella variabilis* n. gen. et sp., *Oedogonium cyathigerum* forma, *Penium margaritaceum, Pleurotaenium ehrenbergii, Closterium pritchardianum, Cosmarium granatum* var. *africanum, C. pseudobroomei* var. *compressum* forma, *Mougeotia* sp., *Spirogyra* sp., *Oscillatoria irrigua, Synedra longissima.*)

277 (85). Attached in running water, near Polo ground, Maritzburg, July 8. (*Stigeoclonium* sp., *Oedogonium* sp., *Spirogyra* sp., *Penium margaritaceum, Cosmarium boeckii, Oscillatoria tenuis, Synedra ulna* var. *aequalis, Nitzschia sigmoidea, Cymatopleura solea* var. *pygmaea.*)

278 (87). In running water, Dorp Spruit, Maritzburg, July 12. (*Stigeoclonium tenue.*)

279 (88). In running water, Dorp Spruit, Maritzburg, July 12. (*Synedra ulna* var. *aequalis, S. vitrea, Navicula vulgaris, N. rhynchocephala, Nitzschia sigmoidea.*)

280 (89). In damp shaded crevice of rock, Town Hill, Maritzburg, July 12. (*Dichothrix* sp., *Synedra vitrea, Achnanthes exigua, Navicula elliptica, N. vulgaris, N. radiosa, N. borealis, N. viridis* var. *elliptica, Gomphonema* spp., *Surirella biseriata.*)

281 (90). On a moist bank of streamlet near railway workshops, Maritzburg, July 10. (Moss protonema.)

282 (91). In semi-stagnant water of pool in streamlet, branch of Dorp Spruit, Maritzburg, July 12. (*Zygnema* sp., *Pleurotaenium ehrenbergii, Closterium pritchardianum, Cosmarium pachydermum* var. *aethiopicum* forma, *Navicula zellensis, N. rhynchocephala, N. interrupta, N. madagascariensis, Gyrosigma acuminatum, Cymbella helvetica* var. *africanum* n. var., *Nitzschia sigma, N. clausii, Surirella splendida.*)

283 (92). Among mosses in dripping water, Sweetwaters Bush, Maritzburg, August 2. (*Calothrix gelatinosa* n. sp.)

284 (93). Encrusting moist decomposing sandstone, aerial, Sweetwater, Maritzburg, August 2. (*Dasygloea amorpha* var. *africana* n. var.)

285 (94). On moist sandstone rocks, Sweetwaters Bush, Maritzburg, August 2. (Only moss protonema.)

286 (95). Blue-green to black surface-film on sandstone rock, Sweetwater, Maritzburg, August 2. (*Tolypothrix arenophila.*)

287 (96). Green scum completely covering surface of pond in Alexandra Park, Maritzburg, August 8.   (*Euglena* sp.)

288 (97). On tops of flower-pots, Natal University College, August 31. (*Vaucheria sessilis, V. hamata, Zygnema* sp., *Microcoleus vaginatus*.)

289 (98). On damp soil, Maritzburg, September 5.   (*Botrydium granulatum. Vaucheria pseudomonoica* n. sp., *Microcoleus annulatus* n. sp., *Arthrodesmus triangularis* forma, *Navicula borealis, N. vulgaris, Stauroneis acuta*.)

290 (100). Near edge of flowing water, Umsindusi, 10 miles below Maritzburg, September 5.   (*Navicula cincta, N. rhynchocephala, N. crypto-cephala, Gyrosigma acuminatum, Nitzschia sigmoidea, N. palea, Surirella apiculata*.)

291 (101). Large gelatinous masses floating on surface of clear sunny pools in bed of Tugela, Drakensberg, Goodoo, 4500 ft. altitude, September 20.   (*Rivularia natans*.)

292 (102). Attached and covering face of dripping crags of waterfall, Tugela Gorge, Drakensberg, altitude 6500 ft., September 19.   (*Cladophora crispata, Spirogyra* sp., *Oedogonium* sp., *Epithemia turgida*.)

293 (103). On dead twig from bed of Makai River, Drakensberg, Goodoo Pass, September 18. · (*Chantransia chalybaea* overgrown with *Chamae-siphon incrustans, Oncobyrsa rivularis, Pediastrum boryanum* var. *longicorne* f. *granulata*.)

294 (105). Lithophytes on cliffs, covering hundreds of square yards, Tugela Gorge, Drakensberg, altitude 7000 ft., September 20.   (*Stigonema informe, S. hormoides* var. *africana* n. var., *S. ocellatum* var. *braunii, Calothrix parietina* var. *africana* n. var., *Schizothrix muelleri, S. epiphytica* n. sp., *Gloeocapsa sanguinea*.)

295 (106). In dripping water on cliffs, Drakensberg, Goodoo Pass, altitude 6500 ft., September 9.   (Mainly *Nostoc microscopicum* ? ; *Oocystis solitaria* var. *pachydermum, Cosmarium cucurbitinum* var. *subpolymorphum, C. punctulatum, Chroococcus turgidus, Chlamydomonas* sp., *Oedogonium* sp., *Epithemia sorex, E. turgida, Cymbella delicatula*.)

296 (107). Floating in pools in Tugela River, Drakensberg, altitude 4500 ft., September 19.   (*Zygnema* sp., *Anabaena* sp.)

297 (108). Covering bed of Tugela in quiet clear sunny pools, Drakens-berg, altitude 4500 ft., September 19.   (*Synedra longissima* and var. *acicularis, Navicula bisulcata* var. *turgidulum, Gomphonema brachyneura, G. parvulum, Epithemia sorex, E. zebra* var. *porcellus, Rhopalodia parallela, Nitzschia communis*.)

298 (109). On moist cliff, Drakensberg, Goodoo Pass, altitude 6500 ft., September 18.   (*Scytonema splendens* n. sp., *Gloeocapsa alpina* ?)

299 (110). On moist faces of cliffs, Goodoo Pass, altitude 4500 ft.,

September 19. (*Zygnema* sp., *Scytonema splendens* n. sp., *Epithemia sorex* forma, *E. turgida, Rhopalodia ventricosa.*)

300 (111). Attached to submerged boulders in quiet sunny pool, bed of Tugela River, altitude 4500 ft., September 20. (*Spirogyra* sp., *Navicula radiosa, N. major, N. mesolepta* var. *africana* n. var., *Rhopalodia* spp., *Synedra* spp.)

301 (112). On damp soil in shady cave, near Tugela, Drakensberg, altitude 5000 ft., September 19. (*Vaucheria pseudomonoica, Rhopalodia ventricosa.*)

302 (113). Moist lithophytes from foot of a waterfall, Goodoo Pass, Drakensberg, altitude 6000 ft., September 19. (*Calothrix parietina* var. *africana* n. var., *Scytonema myochrous, Gloeocapsa rupestris, G. alpina.*)

303 (114). Gelatinous clumps among Hepatics, near Tugela, Drakensberg, altitude 4500 ft., September 19. (*Nostoc* sp., *Cosmarium gayanum* var. *rotundata* forma, *Synedra ulna, S. longissima, Navicula elliptica, N. borealis, N. mesolepta* and var. *africana* n. var., *Gomphonema crassestriatum* n. sp.)

304 (116). In full sunlight, in streamlet flowing over cliff, Tugela Gorge, Drakensberg, altitude 6000 ft., September 19. (*Spirogyra* sp., *Oedogonium* sp., *Synedra longissima* and var. *acicularis, Gomphonema crassestriatum* n. sp.)

305 (117). In moist, sunny rock crevices, Tugela Gorge, altitude 6500 ft., September 19. (*Nostoc* sp., *Gloeocapsa punctata,* etc., *Spirogyra* sp., *Gonatozygon brebissonii, Cosmarium granatum* var. *africanum, C. punctulatum, C. gayanum* var. *rotundata* forma, *Closterium leibleinii* forma, *Oocystis solitaria* var. *pachyderma, Oedogonium* sp., *Navicula elliptica, N. tenella, Epithemia* spp., *Rhopalodia* spp.)

306 (118). In constant drip on moist shady cliff, Tugela Gorge, altitude 6500 ft., September 19. (*Schizothrix fuscescens* forma, partly colonised by *Calothrix braunii* forma.)

307 (119). Greyish-green covering to face of rock, cliff waterfall, Tugela Gorge, altitude 6500 ft., September 19. (*Oedogonium* spp., abundant Diatoms, especially *Gomphonema brachyneura, Cymbella maculata* forma, *Epithemia sorex* forma.)

308 (121). On dripping crags, Tugela Gorge, altitude 6500 ft., September 19. (*Gloeocapsa sanguinea, G. alpina, Scytonema myochrous* forma.)

309 (123). Attached in waterfall at side of Tugela Gorge, sunny, altitude 6500 ft., September 20. (*Nostoc* sp., *Spirogyra* sp., *Oedogonium* sp., *Closterium leibleinii* forma, *Cosmarium punctulatum, Scytonema myochrous* forma, *Gloeocapsa* sp., *Cladophora* sp. with epiphytic Diatoms, *Melosira roeseana, Synedra longissima, Cymbella helvetica* var. *africana* n. var., *C. maculata* forma, *Epithemia* spp., *Rhopalodia* spp.)

310 (125). Attached to submerged rocks, in clear water, in pools of Tugela River, Drakensberg, altitude 6500 ft., September 20. (*Chantransia* sp., *Oedogonium borisianum, Gloeocapsa* sp., *Stauroneis anceps* var. *birostris, Cymbella helvetica* var. *africana* n. var., *C. maculata* forma, *Epithemia* spp., *Surirella splendida.*)

468 (coll. G. C. Nel). In damp shady place on ground, Mountain View, Greytown, January 17, 1921. (*Mougeotia* sp., *Oedogonium* sp., *Ulothrix* sp., *Hormidium subtile, Cosmarium gayanum* var. *rotundata* forma, *C. pseudobroomei* var. *compressum* forma, *Navicula interrupta, N. viridis* var. *elliptica, N. anglica* var. *minuta, Gomphonema parvulum.*)

469 (coll. G. C. Nel). On moist places of brick wall, Greytown, January 18, 1921. (*Hormidium flaccidum, Coccomyxa subellipsoidea* ?)

470 (coll. G. C. Nel). In swift running water in shaded part of water-fall, Berwing, Greytown, January 19, 1921. (*Cladophora* sp., *Cosmarium pseudobroomei* var. *compressum* forma, *Synedra ulna* var. *aequalis, Eunotia lunaris, Navicula anglica* var. *minuta, Gomphonema brachyneura, Cymbella ventricosa* var. *obtusa.*)

Previous records for South Africa are mentioned under the individual species. The number of new records for South Africa in the present communication is 145 (*cf.* table on p. 298), which is high by comparison with the total number of species found.

C. SYSTEMATIC ENUMERATION OF THE SPECIES OBSERVED.

I. ISOKONTAE.

(a) CHLAMYDOMONADALES.

(2) CHLAMYDOMONADACEAE.

GENUS CHLAMYDOMONAS EHRENBERG.

(NOTE.—Individuals of this genus were only observed in samples 230, 243, and 295, the preservation of the material not admitting of specific determination.)

(d) PROTOCOCCALES.

(4) HYDRODICTYACEAE.

GENUS PEDIASTRUM MEYEN.

1. *Pediastrum boryanum* (Turp.), Menegh.; Naegeli, Gatt. einzell. Algen, 1849, p. 95, Tab. V, B, fig. 1; Brunnthaler, Suesswasserfl., v, 1915, p. 100.

Var. *longicorne*, Reinsch, forma *granulata*; Brunnthaler, *op. cit.*, p. 101.

Sample 293 (very rare).

The type already recorded from the Karoo and the neighbourhood of Cape Town.

2. *Pediastrum tetras* (Ehrenb.), Ralfs, Brit. Desm., 1848, p. 182, Tab. XXXI, fig. 1. (Syn.: *P. ehrenbergii*, Corda.)

Samples 230, 246, and 305 (not at all common, except in the last.)
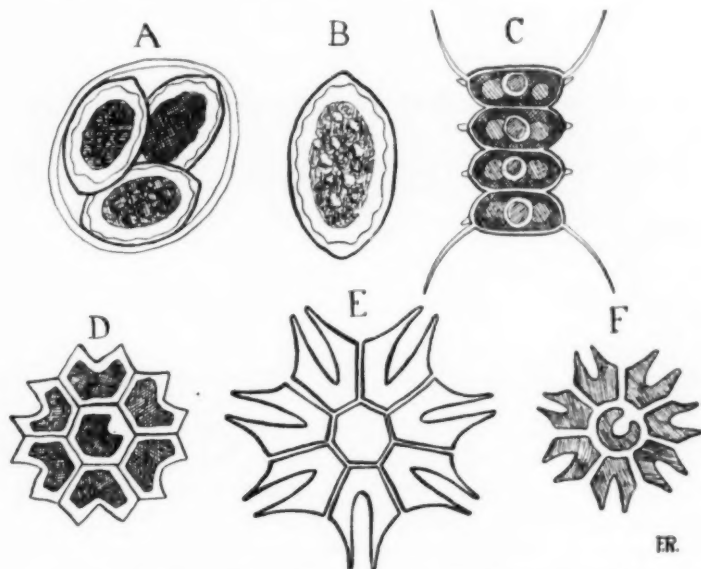
Fig. 1.—*A* and *B*, *Oocystis solitaria*, Wittr., var. *pachyderma*, Printz, f. *undulata* (×1600). *C*, *Scenedesmus quadricauda* (Turp.), Bréb., var. *africana*, Fritsch and Rich, n. var. (×700). *D–F*, Forms of *Pediastrum tetras* (Ehrenb.), Ralfs. *D*, form approaching *P. angulosum*, Menegh. (×700). *E*, *F*, forma *b*, W. & G. S. West, 1895 (×1300).

The specimens (Fig. 1, *E* and *F*) closely resembled the forma *b* of Messrs. West * (Trans. Linn. Soc. London, Bot., v, 1895, p. 81, Pl. IX, fig. 39), except for slight differences in the shape of the incisions between the marginal processes. This same form is recorded by G. M. Smith (Bull. Wisconsin Geol. and Nat. Hist. Survey, No. 57, Scient. Ser., No. 12, 1920, p. 174, Pl. XLVIII, figs. 13, 14) as var. *tetraodon* (Corda), Hansg., which is

* In Brunnthaler (*op. cit.*, p. 104), a wrong reference to the figures on p. 103 is given; his fig. 64, *b*, shows Messrs. West's forma *b*, and his fig. 64, *c*, West's forma *a*.

not in agreement with the diagnoses in Hansgirg (Prodr. Algenfl. Boehmen, i, 1888, p. 112) or Brunnthaler (*op. cit.*, p. 103), where the marginal cells are described as " vierspitzig."

In sample 305 a form (Fig. 1, *D*) occurred closely allied to *P. angulosum* (Ehrenb.), Menegh. (*cf.* especially the figure in Ralfs, *op. cit.*, fig. 11, *A*).

This species has already been recorded from Cape Colony.

(5) CHLORELLACEAE.

Genus COCCOMYXA Schmidle.

1. *Coccomyxa subellipsoidea*, Acton, Ann. of Bot., xxiii, 1909, p. 573 *et seq.*, Pl. XLIII.

Sample 469 (abundant, intermingled with *Hormidium flaccidum*).

In view of the shrunken nature of the cell-contents this determination is open to some doubt.   A pyrenoid was recognisable only in some of the cells which show the same variable shape as described by Acton (*cf.* also Pascher, in Suesswasserflora, v, 1915, p. 210).

(6) OOCYSTACEAE.

Genus OOCYSTIS Naegeli.

1. *Oocystis crassa*, Wittr. ;   Printz, Syst. Uebers. d. Gatt. *Oocystis*, Naeg., Nyt Mag. f. Naturvidenskab, li, 1913, p. 175, Tab. IV, figs. 12–14 ; Brunnthaler, *op. cit.*, p. 125.

Forma ad *O. marssonii*, Lemm. accedens. Long. cell., 16–21 μ ; lat. cell., 10–13 μ ; lat. colon. 8–cell., 32 μ.

Sample 246 (not uncommon).

This is a form of *O. crassa* approaching *O. marssonii*, Lemmerm., which Printz and others regard but as a variety of the former species.   The cells were slightly thickened at either pole and were either solitary or, rather frequently, occurred in eight-celled colonies with a close-fitting investment. There were usually only about four chloroplasts per cell.   The poles of the cells were either rounded or more or less pointed, but not as pronouncedly as in *O. marssonii*, Lemm.

2. *Oocystis solitaria*, Wittr. ;   Printz, *op. cit.*, p. 183.

Var. *pachyderma*, Printz, *op. cit.*, p. 186, Tab. V, figs. 57–59 (Fig. nostr. 1, *A* and *B*).

Samples 295 (common), 305 (not uncommon).

Long. cell., 27–38 μ ; lat. cell., 19–24 μ. Most of the specimens in sample 305 showed a peculiar undulation of the inner edge of the thick membrane (f. *undulata*, Fig. 1, *A, B*). Nearly all the colonies observed had only two individuals in them.

The type has already been recorded from Cape Colony and Orange Free State.

(NOTE.—Individuals of this genus, in too small quantity to be determinable, were also observed in samples 229 and 261.)

(7) SCENEDESMACEAE.

GENUS SCENEDESMUS MEYEN.

1. *Scenedesmus bijugatus* (Turp.), Kuetz.; Brunnthaler, *op. cit.*, p. 167. (Syn. : *S. obtusus*, Meyen.)

Var. *alternans* (Reinsch), Hansg.; Brunnthaler, *op. cit.*, p. 167, fig. 234. (Syn. : *S. alternans*, Reinsch.)

f. *apiculata* (West), Brunnthaler. (Syn. : *S. alternans*, Reinsch, var. *apiculatus*, W. & G. S. West, Journ. Roy. Microscop. Soc., 1894, p. 16, fig. 38.)

Sample 246 (rare).

The type has already been recorded from various localities in South Africa.

2. *Scenedesmus quadricauda* (Turp.), Bréb.; Brunnthaler, *op. cit.*, p. 165.

Var. *africana*, Fritsch and Rich, nov. var. (Fig. 1, *C*).

Coloniis quadricellularibus, cellulis internis subhexagonis, iis externis subtrapeziformibus ; apicibus cellularum omnium spina breve singula munitis, cellulis externis etiam spinis longis usitatis.

Long. cell., 17–22 μ ; lat. colon. 4-cell., 24–36 μ.

Sample 230 (rather rare).

The type is known from various parts of South Africa.

GENUS ANKISTRODESMUS CORDA (RHAPHIDIUM KUETZ.).

1. *Ankistrodesmus falcatus* (Corda), Ralfs, Brit. Desm., 1848, p. 180. (Syn. : *Rhaphidium fasciculatum*, Kuetz.; *R. polymorphum*, Fresen. var. *falcatum*, Rabenh.).

Sample 246 (rare).

Already known from various parts of South Africa.

22

(e) ULOTRICHALES.

(1) ULOTRICHACEAE.

GENUS ULOTHRIX KUETZING.

1. *Ulothrix aequalis*, Kuetz. ; Heering, Suesswasserfl., vi, 1914, p. 35, fig. 33.

Samples 215, 221.

2. *Ulothrix oscillarina*, Kuetz. ; Heering, *op. cit.*, p. 32.

Sample 221.

Diam. fil., 8–11 μ.

Previously recorded from Table Mountain.

3. *Ulothrix variabilis*, Kuetz. ; Heering, *op. cit.*, p. 32, fig. 27.

Sample 257.

Previously recorded from Cape Colony.

(NOTE.—A species of *Ulothrix* present in sample 468 was not in a condition admitting of determination.)

GENUS HORMIDIUM KLEBS.

1. *Hormidium flaccidum*, A. Braun ; Heering, *op. cit.*, p. 46, figs. 48, 49.

Sample 469.

Previously recorded from Kentani.

2. *Hormidium subtile* (Kuetz.) ; Heering, *op. cit.*, p. 47, fig. 54.   (Syn. : *Stichococcus subtilis*, Klercker.)

Sample 468.

Previously recorded from Table Mountain.

GENUS PEARSONIELLA * FRITSCH and RICH, nov. gen.

Filis vegetativis elongatis, non ramosis, cellulis in serie unico, perraro septis longitudinalibus praeditis ; cellulis deplanatis vel subquadratis vel diametro longioribus ; membrana saepe paullo incrassata et gelatinosa. Chromatophora in quaque cellula singula forma cinguli cylindracei integri, pyrenoidibus magnis pluribus sparsis munita.   Nucleus singulus, plerumque in media cellula.   Propagatio vegetativa fit disruptione filorum ubi constrictiones vel cellulae biconcavae adsunt.

1. *Pearsoniella variabilis*, Fritsch and Rich, n. sp. (Fig. 2).

* Named after the late Professor H. H. W. Pearson, F.R.S., to whom this series of papers on African Algae owed its origin.

Filis inter cellulas passim, raro inter cellulas successivas, constrictis ; cellulis deplanatis vel subquadratis vel diametro longioribus. Chromatophoris in cellulis brevioribus (juvenalibus ?) marginibus integerrimis, in cellulis elongatis (maturis ?) interdum marginibus plus minus lobatis vel subreticulatis, pyrenoidibus magnis pluribus irregulariter dispersis. Membrana cellularum vulgo paullo incrassata, interdum obscure lamellata.

Diam. fil., 21–35 μ.

Samples 214 (common), 276 (rare).
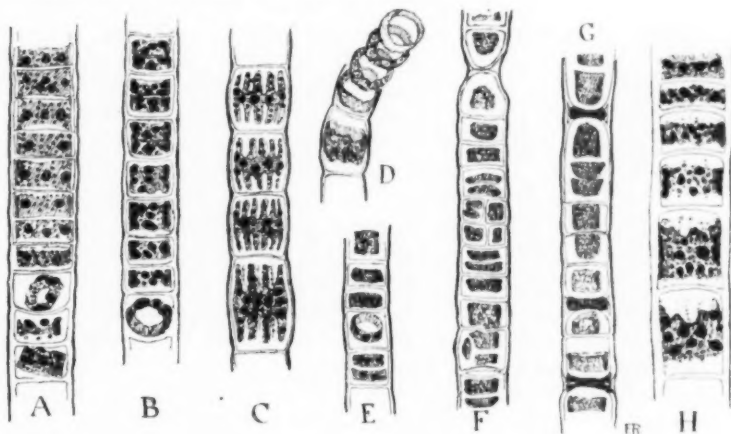
Fig. 2.—*Pearsoniella variabilis*, Fritsch and Rich, n. sp. Portions of various filaments. The typical shape of the chloroplast is well seen in figs. *A*, *B*, *D*, *E*, and *H*. In *H* the usual form of chloroplast (with a slightly lobed edge), seen in the more elongated cells, is illustrated. *C* shows the very exceptional condition of constriction between successive cells and extreme lobing of the chloroplast-edge. Longitudinal division of cells is seen in *F*, a thread which also shows the customary occasional constriction of the threads preparatory to fragmentation. Biconcave cells are seen in *G*. *C* and *H* × 450, all other figures × 250.

This is a striking new genus of Ulotrichales, of which a second species has been found in collections from Transvaal which are at present under investigation. It is essentially characterised by its chloroplasts, which assume a form, as far as we are aware, not yet recorded among the Algae, viz. that of a complete ring or girdle encircling the periphery of the cell. In flat (presumably young) cells the chloroplast has the shape of a very low, hollow cylinder (Fig. 2, *A*, *B*, *D*, *E*, *H*) with an entire edge ; such chloroplasts already contain a number of, often rather irregularly distributed, pyrenoids which are frequently quite conspicuous, giving the annular structure a great superficial resemblance to a coil of a chloroplast of *Spirogyra* (Fig. 2, *D*). In the longer, and presumably older, cells the cylindrical

chloroplast becomes more elongated and is not uncommonly slightly lobed at the margin (Fig. 2, *D* and *H*). The pyrenoids are numerous and quite irregularly distributed through the substance of the chloroplast ; as a general rule the central body and the enveloping sheath of starch are plainly visible after staining with iodine. In these larger cells it not uncommonly has the appearance as though segmentation of the chloroplast around the individual pyrenoids had taken place ; whether this is really the case, should be capable of being settled by an examination of fresh material. The components certainly remain cohering together as a cylindrical group. A very rare condition of the chloroplast is shown in Fig. 2, *C* ; here it is drawn out into a number of lobes at either end, whilst still retaining the cylindrical form. It is not altogether clear how this condition arises, whether by outgrowth of processes from the edges or by breaking down of the intervening parts of the chloroplast. Since incipient splits can often be observed within the lobes, it would seem that the second alternative is more likely to be correct. This probably represents a senile condition.

The transverse walls of the cells are at first very thin and appear to push their way from the periphery through the substance of the chloroplast (Fig. 2, *B*, upper part). In many cases chloroplasts, which casually examined under low power seem to be quite homogeneous, are seen under a higher power to be divided into two portions by a thin septum. Later the transverse walls become somewhat thicker and the chloroplast in each daughter-cell is found to terminate a little distance from the septum.

The longitudinal walls are not usually very markedly thickened, are sometimes obscurely stratified, and frequently have a somewhat gelatinous appearance like that of the cell-walls of Conjugatae. In this connection mention may be made of the fact that no epiphytes were observed on the filaments. As a general rule there is no constriction between the individual cells (*cf.* however, Fig. 2, *C*), but at more or less frequent points marked constrictions occur (Fig. 2, *F*). At these places the transverse septa tend to split, at the same time becoming more or less markedly thickened, and this seems to represent one of the customary methods of vegetative propagation of the Alga. In addition to this occasional biconcave cells with denser contents, similar to those recorded in other members of the Ulotrichales, have been observed (Fig. 2, *G*) ; these no doubt also mark points of fragmentation. No other methods of reproduction have been seen.

There appears to be a single, moderately large nucleus in each cell, suspended in the centre within a transverse bridge of cytoplasm.

There can be little doubt that this form should find its place among the Ulotrichaceae, where chloroplasts which are segments of a hollow

cylinder are of common occurrence. In fact one would appear to have in *Pearsoniella* the central type from which all the other chloroplasts of Ulotrichales could be derived, and itself evidently the form one would obtain if the spherical chloroplast, typical of so many Protococcales, were to undergo transverse septation. The occasional longitudinal division of the cells and the mode of fragmentation of the threads are also paralleled among other members of the Ulotrichaceae. There is a certain amount of resemblance, especially at the stage shown in Fig. 2, *C*, to *Ulothrix gelatinosa*, Fritsch (Ann. S. Afr. Mus., ix, p. 516, fig. 11), but here the chloroplast is not a complete cylinder, but only a segment as in other species of *Ulothrix*. Still the gap between the two forms is not too great. The chloroplast of *Ulothrix gelatinosa* serves to connect that typical of *Ulothrix* with the Chaetophoraceous type, so that the study of South African Algae has already materially advanced our knowledge of the Ulotrichaceous chloroplast.

Genus SCHIZOMERIS Kuetzing.

1. *Schizomeris irregularis*, Fritsch and Rich, n. sp. (Fig. 3).

Filis primum uniseriatis latitudine aequali, plantis aquaticis cellula basali rotundata adhaerentibus ; postea latitudine inaequali et irregulariter multiseriatis per dissepimenta diverse disposita quae cellulas in segmentis formae magnitudinisque variabilis dividunt. Chromatophoris in cellulis juvenalibus singulis formae laminae incurvae pyrenoidibus 3–5 munitis, in cellulis maturis (dissepimentis divisis) aut singulis pyrenoidibus multis aut pluribus pyrenoidibus singulis. Membranis longitudinalibus cellularum plus minus gelatinosis et lamellatis. Propagatio vegetativa fit disruptione filorum ubi constrictiones adsunt. Lat. fil., 21–37 μ.

Sample 255 (not uncommon).

As in the case of *Schizomeris leibleinii*, the young filaments of this species show a considerable resemblance to those of *Ulothrix zonata*, each cell having a curved plate-shaped chloroplast with a number of pyrenoids ; in many of the cells, however, the edges of the chloroplasts are not only incurved at the sides, but also at the two ends of the cells (Fig. 3, *D*). Subsequently the cells of these uniseriate filaments undergo irregular division, leading to the production of multiseriate threads with cells of quite uneven shape and size (Fig. 3, *A*, *C*, *D*, *E*). In this respect the present species differs from all the published figures of *S. leibleinii* to which we have had access (*cf.* Rabenhorst, Fl. Europ. Alg., iii, 1868, p. 289 ; Hansgirg, Prodr. Algenfl. Boehmen, i, 1888, p. 55 ; Migula, Kryptogamenflora, ii, 1907, Pl. XXXVI, ʙ, fig. 11), in which the cells appear arranged very regularly in groups of two and four. Hazen (Ulotrichaceae and Chaeto-

phoraceae of the United States, 1902, p. 188) also speaks of " brick-like arrangement of the cells " in this species. Furthermore, Migula's figure (reproduced by Heering, in Suesswasserfl. Deutschlands, etc., vi, 1914, p. 38) shows only a single pyrenoid in the chloroplast, whereas in *S. irregularis*
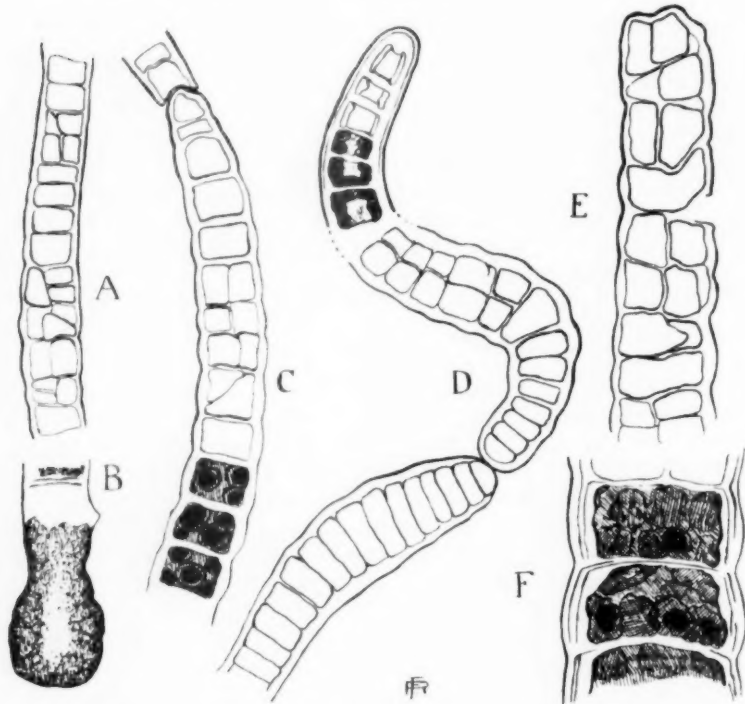
Fig. 3.—*Schizomeris irregularis*, Fritsch and Rich, n. sp.   Various stages in the irregular subdivision of the threads are shown in *A, C, D,* and *E,* the basal attaching cell in *B,* fragmentation of the threads in *C* and *D,* and chloroplast-structure in *C, D,* and *F.   F × 1000,* other figures × 400.

there are several, both in the cells of the young uniseriate filaments and at later stages (Fig. 3, *C*).   In the older filaments we have not been able to determine satisfactorily whether there is a single folded chloroplast with several pyrenoids, or several separate chloroplasts in contact with each other, each bearing one pyrenoid (*cf.* Fig. 3, *F*).   There seems to be a single nucleus in each cell.

A third point of difference from *S. leibleinii* lies in the width of the threads, which never attained to anything approaching the dimensions

recorded for the latter species.   On the other hand the two species resemble one another in the very uneven width of the older filaments, which occasionally show very marked constrictions (Fig. 3, *C* and *D*).   At these points splitting readily occurs, whereby vegetative multiplication is brought about ; the transverse septum often becomes strongly thickened before splitting takes place, and such thickened half-septa are not uncommonly to be found at the narrow ends of detached filaments.   The longitudinal walls are always more or less thickened and stratified (Fig. 3, *F*) and present a gelatinous appearance, although never markedly mucilaginous ; the variously orientated walls separating the cells of older threads are usually thin.   Young and sometimes older threads appear to be attached by a bluntly rounded and somewhat enlarged basal cell (Fig. 3, *B*).

In 1920, S. L. Ghose described an *Uronema indicum* (Ann. Bot., xxxiv, 1920, pp. 95–98) which, in view of the septation of the older threads, had better be designated *Schizomeris indicum*.   The septation is somewhat irregular, but not as markedly so as in our species ; moreover, Ghose's form is characterised by the acuminate apices of the threads.

The older filaments of *S. irregularis* show some resemblance to stages of *Ulothrix mucosa* figured by Cienkowski (Bull. Acad. Imp. Sci. St. Péters-bourg, ix, 1876, figs. 46, 47), but these are preparatory to the formation of *Palmella*-stages, of which there was no evidence in our material.   Nor does their occurrence invalidate the specific independence of the forms here considered as belonging to *Schizomeris*.   The fact that they resemble species of *Ulothrix* or *Uronema* in the juvenile condition is no proof of identity, since the same is the case with some species of *Enteromorpha*.

(6) CLADOPHORACEAE.

Genus CLADOPHORA Kuetzing.

1. *Cladophora crispata* (Roth), Kuetzing, Phyc. generalis, 1843, p. 264 ; Heering, Suesswasserflora, vii, 1921, p. 40.

Samples 250, 292.

Previously recorded from the Cape.

(Note.—Indeterminable material of *Cladophora* was also present in samples 309 and 470.)

(*f*) CHAETOPHORALES.

(1) CHAETOPHORACEAE.

Genus STIGEOCLONIUM Kuetzing (MYXONEMA Fries).

1. *Stigeoclonium falklandicum*, Kuetzing, Tab. Phyc., iii, 1853, Tab. II ; Heering, Suesswasserflora, vi, 1914, p. 71, fig. 94.

Sample 214 (not uncommon).

This is practically the same form as has been recorded from Kentani, the threads showing frequent constrictions between the cells. While the branching as a whole was not very abundant, a very few of the longer terminal branches bore numerous fine branchlets. Occasionally the upright threads were found arising to the number of several from a prostrate filament composed of almost isodiametric cells and itself unbranched. The filaments were up to 11 μ in diameter, and the cell-walls were rather thick for a species of this genus.

2. *Stigeoclonium tenue* (Ag.), Kuetzing, Phyc. generalis, 1843, p. 253; Heering, *op. cit.*, p. 78.

Sample 278 (not uncommon).

Previously recorded from Little Namaqualand.

(NOTE.—Indeterminable species of this genus were also seen in samples 255 and 277.)

(g) OEDOGONIALES.

(1) OEDOGONIACEAE.

GENUS OEDOGONIUM LINK.

1. *Oedogonium borisianum* (Le Cl.), Wittr.; Hirn, Monogr. u. Iconogr. d. Oedogoniaceen, 1900, p. 217, Tab. XXXVI, fig. 233.

Sample 310.

Crass. cell. veg., usque 21 μ; crass. cell. suffult., 36 μ; crass. oogon., 48 μ; crass. oospor., 45 μ.

2. *Oedogonium cyathigerum*, Wittr.; Hirn, *op. cit.*, p. 252, Tab. XLIII, fig. 265.

Forma oosporis saepe globosis, cellulis suffultioribus non semper evidenter inflatis. Crass. cell. veg., 18–24 μ; crass. cell. suffult., 26–30 μ; crass. oogon., 48–55 μ; crass. oospor., 43–48 μ (Fig. 4, *A–C*).

Sample 276.

3. *Oedogonium fragile*, Wittr.; Hirn, *op. cit.*, p. 96, Tab. V, fig. 33.

Sample 241.

4. *Oedogonium rigidum*, Hirn, *op. cit.*, p. 237, Tab. XL, fig. 244 (Fig. nostr. 4, *D–F*).

Sample 246 (rather rare).

The relatively few fertile threads of this form that were present agreed well with the figures and description in Hirn, except that the oospores did not always completely fill the oogonia. A 2-celled androsporangium was only observed on one thread and was hypogynous (Fig. 4, *E*). Opening of the oogonia takes place by means of a superior operculum (Fig. 4, *D*).

In one case numerous dwarf-males, all of which were one- or two-celled, were found seated on the oogonia (Fig. 4, *E*). The dimensions were : crass. cell. veg., 12–14, 5 μ ; crass. oogon., 36–42 μ ; crass. oospor., 30–36 μ.
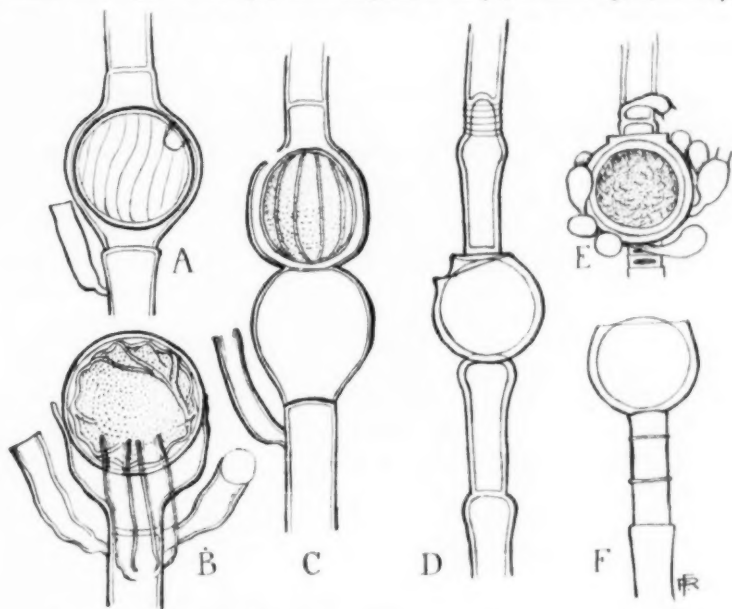
Fig. 4.—*A–C, Oedogonium cyathigerum*, Wittr., forma. *D–F, O rigidum*, Hirn. All figures × 400.

As far as we are aware, this species has only been recorded from South America.

(Note.—Sterile, and therefore not determinable, material of *Oedogonium* was encountered in the following samples : 238, 243, 251, 253, 255, 257 (too few oogonia to be determinable), 262, 265, 272, 274, 275, 277, 292, 295, 304, 305, 307, 309, and 468.)

(*h*) SIPHONALES.

(2) VAUCHERIACEAE.

Genus VAUCHERIA De Candolle.

1. *Vaucheria hamata*, Walz ; Heering, Suesswasserflora, vii, 1921, p. 90, fig. 81 ; Suesswasseralg. Schleswig-Holsteins, etc., ii, Jahrb. d. Hamburg. Wiss. Anst., xxiv, 1906, p. 159.

Sample 288 (rare).

2. *Vaucheria pseudo-monoica*, Fritsch and Rich, n. sp. (Fig. 5).

Filis copiose ramosis, dissepimentis transversis passim (in filis fertilibus tantummodo ?) praeditis, membrana plerumque subcrassa, in aspectu superficiali leviter striata.   Antheridia multo frequentiora quam oogonia, saepe singulatim per laterem ramorum longorum qui interdum oogonium terminalem habent.   Oogonia semper singula et semper antheridium singulum (vel interdum 2 ?) apposita, terminalia, vel in ramis longis (*vide supra*) vel in ramis brevibus efformatis cum antheridio unico contiguo.
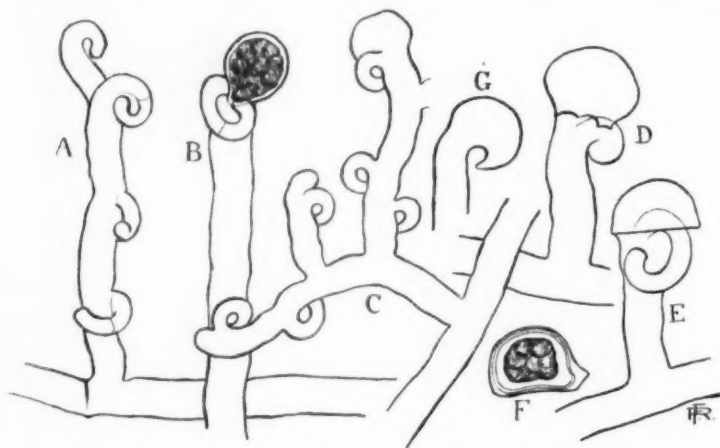
Fig. 5.—*Vaucheria pseudo-monoica*, Fritsch and Rich, n. sp.   The typical long antheridial branches are shown in *A* and *C*, whilst *B* shows a long branch bearing both kinds of sexual organs at its end.   Short branches with sex organs are shown in *D* and *E*.   The form of the oogonia is depicted in *B*, *D*, and *G*, an oogonium with a mature oospore in *B* and *F*.   All figures × 150.

Antheridia circinata, sine cellulis limitandis, ut videtur plerumque multum ante oogonium contiguum evoluta.   Oogonia subsphaerica aut aliquantulum transverse elliptica, papilla dehiscenti valde prominenti antheridium versus spectanti.   Oosporae membrana laevi, oogonium complentes.

Lat. fil., 36–45 μ ; long. oogon., 72–96 μ ; lat. oogon., 56–77 μ ; crass. antherid., 19–24 μ.

Samples 289 (rare), 301 (common).

The most outstanding peculiarity of this species lies in the distribution of the sexual organs.   These are commonly found along the sides, and at the end, of thallus-branches of considerable length.   In such cases an oogonium, if present at all (*cf.* Fig. 5, *A–C*), is always found only at the apex of the branch, where it is associated in the usual manner with one of the

circinately coiled antheridia (Fig. 5, *B*) ; possibly in some cases two antheridia are present. Along the sides of these long branches, however, only antheridia are to be found (Fig. 5, *C*), and the result of this arrangement is that the male organs far outnumber the female. Sexual organs are also occasionally found terminating short lateral branches, the oogonium being terminal and the antheridium arising just below it (Fig. 5, *D*, *E*). The antheridia are separated by a single septum from the branch on which they are borne (Fig. 5, *A*, *B*), and seem to be cut off some time before the adjacent oogonia. The female organs are usually more or less transversely elliptical, in relation to the branch from which they arise (Fig. 5, *B*, *D*, and *G*), and the papilla forming the opening of the mature oogonium is directed downwards towards the adjacent antheridium (Fig. 5, *B* and *D*). The fertile (and sterile ?) parts of the plant are provided with occasional transverse septa which originate as annular ingrowths (Fig. 5, *A*).

A comparison may be instituted in the first place with *V. orientalis*, W. & G. S. West (Ann. Roy. Bot. Gard., Calcutta, vi, 1907, p. 184, Pl. XI, figs. 3–9), in which, as in our species, the threads are relatively fine and rather richly branched. In both cases, too, the sexual organs are usually formed in pairs at the ends of the branches, and are found in these positions both on ordinary long branches and on special short branches. *V. orientalis* does not, however, show the numerous isolated antheridia along the sides of the long branches, as is so characteristic for *V. pseudo-monoica*. The oogonia of the latter, moreover, have a shape different from that found in Messrs. West's species.

There is also some resemblance to *V. hamata*, Walz.

3. *Vaucheria sessilis*, D. C. ; Heering, Suesswasserflora, vii, 1921, p. 87, figs. 74–77 ; Suesswasseralg. Schleswig-Holsteins, etc., *loc. cit.*, p. 143.

Sample 288 (common).

Previously recorded from Kentani.

(*i*) CONJUGATAE.

(1) MESOTAENIACEAE.

Genus SPIROTAENIA Brébisson.

1. *Spirotaenia condensata*, Bréb. ; W. & G. S. West, Monogr. Brit. Desm., Ray Society, i, 1904, p. 38, Pl. II, figs. 7–10.

Sample 246 (rare).

Long. cell., 99–150 μ ; lat. cell., 19–21 μ. The dimensions were thus on the whole less than those given by Messrs. West in their monograph, but such small forms have already been recorded by Boergesen and Nordstedt.

Genus GONATOZYGON De Bary.

1. *Gonatozygon brebissonii*, De Bary ; W. & G. S. West, *op. cit.*, i, p. 31, Pl. I, figs. 8–11.

Forma brevior; long. cell., 75–120 μ; lat. cell., 10–12 μ; membrana minute et dense granulata.

Sample 305 (rather rare).

Some of the individuals present closely resembled var. *laeve* (Hilse), W. & G. S. West (*op. cit.*, Pl. I, fig. 22), in the capitate poles, but differed in the greater width of the cell and the dense granulation of the membrane. There were five pyrenoids in each chloroplast.

Genus NETRIUM Naegeli.

1. *Netrium digitus* (Ehrenb.), Itzigs. & Rothe ; W. & G. S. West, *op. cit.*, i, p. 64, Pl. VI, figs. 14–16.

Samples 242, 246 (common), 253.

Long. cell., 210–300 μ ; lat. cell., 84–129 μ.

Previously recorded from Cape Colony.

2. *Netrium interruptum* (Bréb.), Luetkemueller ; W. & G. S. West, *op. cit.*, i, p. 68, Pl. VII, figs. 1, 2.

Sample 246 (rather rare).

Long. cell., 336 μ ; lat. cell., 77 μ ; lat. apic., 32 μ.

3. *Netrium naegelii* (Bréb.), W. & G. S. West, *op. cit.*, i, p. 66, Pl. VII, figs. 4, 5.

Sample 246 (common).

Long. cell., 83–99 μ ; lat. cell., 30–35 μ.

(2) DESMIDIACEAE.

Genus PENIUM Brébisson.

1. *Penium margaritaceum* (Ehrenb.), Bréb.; W. & G. S. West, *op. cit.*, i, p. 83, Pl. VIII, figs. 32–35.

Samples 276 and 277 (rather rare).

Long. cell., 120–213 μ ; lat. cell., 21–27 μ.

The specimens were quite typical, except for the fact that the membrane was colourless. The type has not previously been recorded from South Africa.

Genus CLOSTERIUM Nitzsch.

1. *Closterium abruptum*, W. West, Journ. Roy. Microscop. Soc., 1892, p. 719, Pl. IX, fig. 1 ; W. & G. S. West, *op. cit.*, p. 158, Pl. XX, figs. 6–10.

Forma *africana*, nov. forma (Fig. 6, *A* and *B*).

Cellulis diametro 6–8 plo longioribus, latioribus quam in typo, apicibus interdum paullulum recurvatis, membrana crassa fuscescenti. Long. cell., 162–200 μ ; lat. cell., 24–26 μ ; lat. apic., 12–13 μ.

Sample 246 (rare).

The general form of the cells is much like that shown in W. West's original figure, but relatively shorter. The figures in the monograph hardly bring out the straight character of the median portion of the cells which is very obvious in the right-hand individual depicted in W. West's figures, and was very noticeable in some of our specimens (Fig. 6, *A*). Certain individuals also showed an obliquely truncate apex (Fig. 6, *A*, *B*),
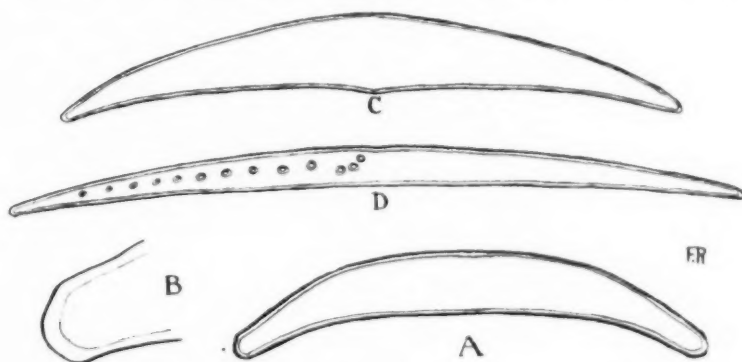
Fig. 6.—*A*, *B*, *Closterium abruptum*, W. West, forma *africana*. *A* × 400, *B* × 1000. *C*, *C. littorale*, Gay, var. *crassum*, W. & G. S. West. × 370. *D*, *C. intermedium*, Ralfs, forma. × 370.

like that visible at the lower end of the right-hand cell in W. West's figure. In some cases the apices were very slightly enlarged.

2. *Closterium intermedium*, Ralfs ; W. & G. S. West, *op. cit.*, i, p. 125, Pl. XIV, figs. 1–5.

Forma apicibus magis attenuatis, 6–7 μ latis, pyrenoidibus in quaque semicellula 12–13. Dist. inter apic., 298 μ ; lat. cell. med., 16 μ (Fig. 6, *D*).

Sample 257 (rare).

Groenblad (Act. Soc. pro Fauna et Flora Fennica, xlvii, p. 18, Tab. IV, figs. 6–9) has already recorded forms of this species with narrower apices than are mentioned in Messrs. West's monograph.

3. *Closterium kuetzingii*, Bréb. ; W. & G. S. West, *op. cit.*, i, p. 186, Pl. XXV, figs. 6–11.

Sample 272 (rather rare).

Dist. inter apic., 360–420 μ ; lat. cell., 18–19, 5 μ.

Previously recorded from Madagascar.

4. *Closterium lanceolatum*, Kuetz.; W. & G. S. West, *op. cit.*, i, p. 149, Pl. XVII, figs. 9, 10.

Samples 241 (rare), 261 (rather common).

Dimensions : long., 352 μ, lat., 45 μ (sample 241); and long., 232–278 μ, lat., 27–30 μ (sample 261). In the individuals found in sample 261 the apices were not as pointed as shown in Messrs. West's monograph, being more like those represented by them in the " Freshwater Algae of Madagascar " (Trans. Linn. Soc. Bot., v, 1895, Pl. IX, fig. 21).

This species has already previously been recorded from various parts of South Africa.

5. *Closterium leibleinii*, Kuetz.; W. & G. S. West, *op. cit.*, i, p. 141, Pl. XVI, figs. 9–14.

Forma minor. Dist. inter apic., 90–165 μ; lat. cell., 15–25, 5 μ.

Samples 244 (rare), 269 (rare), 305 (common), 309 (common).

The individuals present in the different samples varied considerably in size and in the degree of prominence of the median tumidity. Some specimens in 305 approached the var. *minima*, Schmidle (Ber. Deutsch. Bot. Ges., xi, 1893, p. 548, Pl. XXVIII, fig. 1), although more curved.

Forma major. Dist. inter apic., 160–210 μ; lat. cell., 27–32 μ.

Samples 256 (rare), 257 (rather common).

These larger specimens much resembled the forms of *C. moniliferum* (Bory), Ehrenb., figured by Borge (Arkiv f. Bot., viii, 1909, p. 4, fig. 4), although not as wide and without the recurved apices. All such forms could with almost equal justification be referred to either species, according as one lays more stress on the degree of curvature or the size. *C. leibleinii* is already known from various parts of South Africa.

6. *Closterium lineatum*, Ehrenb.; W. & G. S. West, *op. cit.*, i, p. 181, Pl. XXIV, figs. 1–5.

Sample 272 (very rare).

Dist. inter apic., 600 μ; lat. cell., 26 μ.

7. *Closterium littorale*, Gày; W. & G. S. West, *op. cit.*, i, p. 155, Pl. XIX, fig. 14.

Var. *crassum*, W. & G. S. West, Alg. Centr. Africa, Journ. Bot., xxxiv, 1896, p. 378, Tab. CCCLXI, fig. 18 (Fig. nostr. 6, *C*).

Sample 244 (not uncommon).

Dist. inter apic., 234–270 μ; lat. cell., 31–33 μ. It seems probable that f. *crassior*, Borge (Algenfl. d. Tåkernsees, Stockholm, 1921, p. 14, Pl. I, fig. 6) should be merged in this variety.

8. *Closterium malinvernianum*, De Not.; W. & G. S. West, *op. cit.*, i, p. 145, Pl. XVII, figs. 5, 6.

Samples 255 (rather rare), 256, 257 (common in both).

Dist. inter apic., 540–570 μ ; lat. cell., 99–120 μ. Many of the individuals approached forma *major*, Fritsch recorded from Cape Colony (Ann. S. Afr. Mus., ix, 1918, p. 544, fig. 22). Of the differences, mentioned by Messrs. West (*loc. cit.*, p. 146), between this species and *C. ehrenbergii*, Menegh., the coloration and striation of the wall appear to be the only constant ones.

9. *Closterium moniliferum* (Bory), Ehrenb. ; W. & G. S. West, *op. cit.*, i, p. 142, Pl. XVI, figs. 15, 16.

Samples 235 (rare), 241 (rather rare), 257 (rare), 261 (rather rare).

Small individuals ; dist. inter apic., 180–262 μ ; lat. cell., 35–45 μ. Species widely distributed in Africa.

10. *Closterium navicula* (Bréb.), Luetkemueller, Verhandl. Zool.-Bot. Ges., Wien, 1905, p. 332 *et seq.* (Syn. : *Penium navicula*, Bréb. ; W. & G. S. West, op. cit., i, p. 75, Pl. VII, figs. 12–15, 19).

Samples 246, 261 (rather rare in both).

Long. cell., 70–105 μ ; lat. cell., 16, 5–20 μ.

A widely distributed species, but hitherto not recorded from South Africa, though known from Madagascar.

11. *Closterium parvulum*, Naeg. ; W. & G. S. West, *op. cit.*, i, p. 133, Pl. XV, figs. 9–12.

Sample 246 (common).

Dist. inter apic., 101–108 μ ; lat. cell., 14–15 μ.

Already recorded from Cape Colony and Kentani.

12. *Closterium pritchardianum*, Arch. ; W. & G. S. West, *op. cit.*, i, p. 172, Pl. XXII, figs. 6–14.

Samples 241 (common), 244 (rare), 246 (rare), 257 (rare), 261 (rare), 275 (rare), 276 (rare), 282 (common).

Dist. inter apic., 300–500 μ ; lat. cell., 29–45 μ. All of these specimens agree with one another, and differ from those figured in Messrs. West's monograph (*loc. cit.*), in exhibiting a less pronounced recurving of the apices, a feature which, indeed, in some cases, is unrecognisable at one or even at both ends of an individual. Such specimens approach rather closely some forms of *C. acerosum* (Schrank), Ehrenb., but, since all that were closely examined showed clearly the structure of the cell-membrane typical of *C. pritchardianum*, they have all been classed under this species, the more as they were connected by imperceptible transitions with relatively typical individuals exhibiting distinct recurving of the apices. In sample 241 all the individuals seen were practically colourless, possessing at the best but a faint yellow tinge.

Forma *minor*, Fritsch, Ann. S. Afr. Mus., ix, 1918, p. 546, fig. 23.

Sample 244 (common).

Dist. inter apic., 280–320 μ ; lat. cell., 42–46 μ.

C. pritchardianum is very widely distributed in South Africa.

13. *Closterium subulatum* (Kuetz.), Bréb. ; W. & G. S. West, *op. cit.*, i, p. 179, Pl. XXIII, figs. 16–19.

Samples 255 (rather rare), 256 and 257 (not uncommon), 262 (rather rare).

Dist. inter apic., 125–192 μ ; lat. cell., 9–10 μ. From four to seven pyrenoids in each semicell.

Genus PLEUROTAENIUM Naegeli.

1. *Pleurotaenium ehrenbergii* (Bréb.), De Bary ; W. & G. S. West, *op. cit.*, i, p. 205, Pl. XXIX, figs. 9–11.

Samples 276 (not uncommon), 282 (rather rare).

Long. cell., 465–502 μ ; lat. ad inflat. basal., 27 μ ; lat. in media semicellula, 25 μ ; lat. apic., 20 μ.

Previously recorded from Cape Colony.

Forma latior inflatione basali unica, tuberculis apicalibus 6. Long., 495–558 μ ; lat. ad inflat. basal., 39–54 μ ; lat. in media semicellula, 55–63 μ ; lat. apic., 36–42μ.

Sample 246 (rather rare).

All the specimens observed in this sample were larger than the average and were characterised by the presence of only one basal inflation and of only six apical tubercles. Moreover, the individuals were commonly wider at the middle than towards either end of the semicell. In the last two respects they recalled the var. *tumida*, Turner (K. Sv. Vet.-Akad. Handl., xxv, 1892, No. 5, p. 31, Tab. IV, fig. 4), which, however, has far smaller dimensions. This variety is cited in Messrs. West's monograph under the type, but the diagnosis of the latter there given does not embrace the special features mentioned by Turner.

2. *Pleurotaenium ovatum*, Nordstedt, Oefvers. K. Sv. Vet.-Akad. Foerhandl., 1877, No. 3, p. 18. (Syn. : *Docidium ovatum*, Nordstedt, Vid. Med. Nat. Foren. Kjøbenhavn, 1869, p. 205, Tab. III, fig. 37).

Forma angustior, constrictione profundiore. Long. cell., 305–405 μ ; lat. isthm., 39 μ ; lat. max., 78–81 μ ; lat. apic., 33 μ (Fig. 7, *E*).

Sample 272 (rather rare).

This species is evidently widely distributed in South Africa.

3. *Pleurotaenium subcoronulatum* (Turner), W. & G. S. West, Trans. Linn. Soc., Bot., v, 1895, p. 44, Pl. V, fig. 33. (Syn. : *Docidium subcoronulatum*, W. B. Turner, K. Sv. Vet.-Akad. Handl., xxv, 1892, No. 5, p. 29, Tab. III, fig. 1.)

Formae diversae. Long. cell., 570–690 μ ; lat. ad inflat. basal., 38–45 μ ; lat. in media semicell., 35–41 μ ; lat. apic., 33–38 μ (Fig. 7, *A–D*).

Sample 272 (common).

The semicells, which were very slightly attenuated from base to apex, invariably possessed a prominent basal inflation, but for the rest the individuals were rather variable. Some of the semicells were almost straight-sided with a mere suggestion of a waved outline (Fig. 7, *A*), whilst others
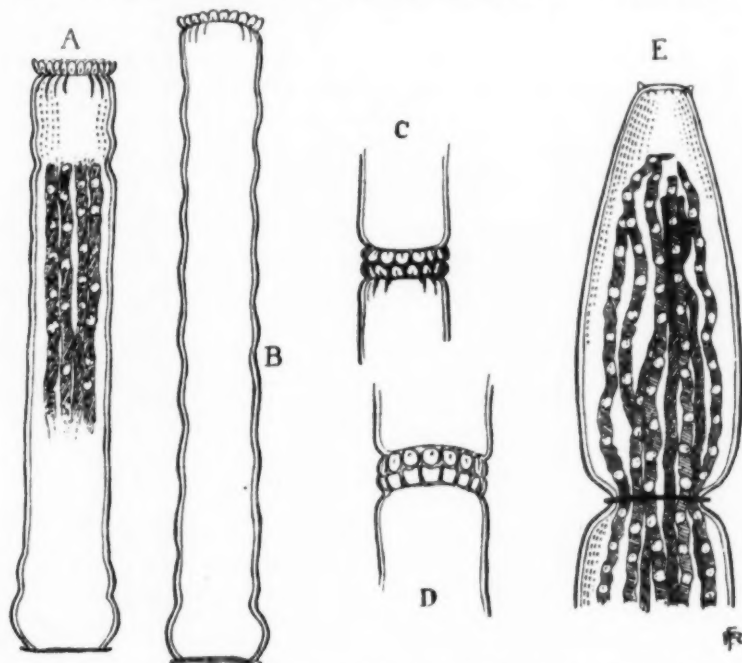
FIG. 7.—*A–D, Pleurotaenium subcoronulatum* (Turner), W. & G. S. West ; *A* and *B*, two semicells ; *C* and *D*, apices of two cohering individuals. *E, Pleurotaenium ovatum*, Nordst., forma angustior. *A* and *B*, × 370, *C* and *D* × 450, *E* × 300.

were more or less undulated along their whole length (*cf.* Turner's original description and our figure 7, *B*). Approximately the last sixth of the lateral margins was usually almost straight (Fig. 7, *C* and *D*) and, where this region commenced, there was often a more or less decided constriction (Fig. 7, *A*), which in the undulate individuals tended to merge in the general waviness of the outline (Fig. 7, *B*). Messrs. West (Trans. Linn. Soc., Bot., v, 1896, p. 235, Pl. XIII, figs. 2, 3) have described a var. *detum of P. sub-coronulatum*, in which the chief characteristic lies in such a subapical constriction. In sample 272 there seemed to be all transitions between

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normal individuals and such as showed clearly this character of var. *detum*, and it is doubtful if this variety can be maintained.

The apices were crowned with a ring of 18–20 molar-shaped tubercles, 9–11 being visible across the apex (Fig. 7, *A*, *B*) ; they often showed the fissure mentioned in Turner's diagnosis.   It would seem from the published figures that these tubercles vary rather considerably in form.   Below them the cell-wall is often slightly fluted (Fig. 7, *A–C*).   The membrane bears irregular punctae which here and there appear in longitudinal rows (Fig. 7, *A*).   The individuals were not uncommonly found cohering by their apices (Fig. 7, *C* and *D*).

The type has been recorded from Madagascar.

4. *Pleurotaenium trabecula* (Ehrenb.), Naeg. ;   W. & G. S. West, *op. cit.*, i, p. 209, Pl. XXX, figs. 11–13.

Samples 269 and 272 (not uncommon).

Long. cell., 310–660 μ ; lat. ad inflat. basal., 21–43 μ ; lat. in media semicell., 28–36 μ ; lat. apic., 17–30 μ.

Genus EUASTRUM Ehrenberg.

1. *Euastrum brasiliense*, Borge, Arkiv f. Bot., i, 1903, p. 112, Pl. V, fig. 1.

Forma cum f. *minor*, Borge (Arkiv f. Bot., xv, 1918, p. 60, Pl. V, fig. 4), valde congruens, sed paullo major ; lateribus loborum lateralium plus minusve parallelis et retusis.   Long. cell., 64–83 μ ; lat. cell., 32–43 μ ; lat. isthm., 12–15 μ (Fig. 8, *A–C*).

Sample 246 (rather rare).

Forma lateribus loborum lateralium convergentibus, forma Borge, *loc. cit.*, p. 60, Pl. V, fig. 5, similis, sed latior et apicibus rotundato-truncatis. Long. cell., 96–102 μ ; lat. cell., 48–52 μ ; lat. isthm., 15–16 μ (Fig. 8, *F*).

Sample 246 (rather common).

Both these forms had the typical rounded central protuberance of *E. brasiliense* and were connected by occasional transitional forms (Fig. 8, *D* and *E*).   They differed considerably among one another in the degree of undulation of the lateral margins.   The membrane was obscurely and irregularly punctate.

Var. *africanum*, Fritsch and Rich, nov. var. (Fig. 9).

E. magnum, longior et pro rata angustior quam typo, profunde con-strictum, sinu angusto-lineari, membrana crassa.   Semicellulae subpyra-midatae, apice lato et truncato ; marginibus lateralibus inferioribus saepe leviter convergentibus, raro subparallelis, obscure undulatis ; marginibus lateralibus superioribus convergentibus et leviter concavis ; incisura apicali non profunda, angustissima et membrana incrassata ; in media semicellula supra isthmum tumore magno truncato membrana incrassata,

tumorem alterius semicellulae contingenti et ca.   Eiusdem latitudinis quam
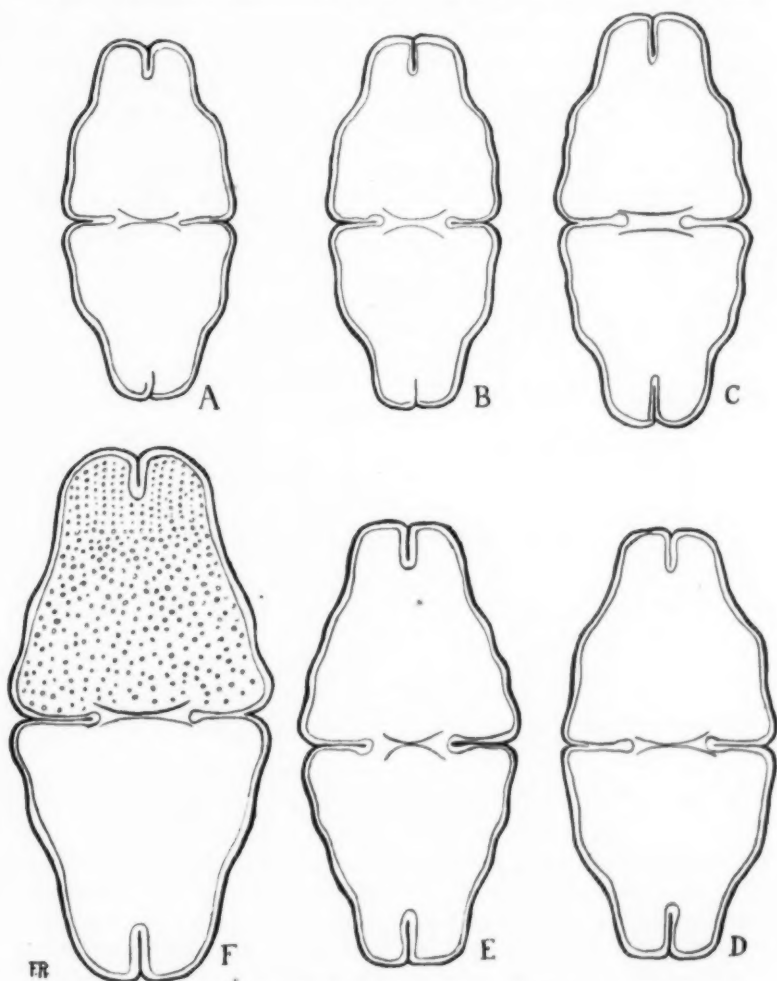
FIG. 8.—*Euastrum brasiliense*, Borge, diverse forms.   *A–C*, forms approaching forma *minor*, Borge.   *F*, form with converging sides.   *D* and *E*, forms transitional between the two preceding.   All figures × 800.

isthmo ; membrana semicellulae vulgo obscure et irregulariter punctata. A latere visae pyramidatae, apice rotundato, tumoribus supra isthmum

sitis a parte superiore incisura lata concava disjunctis. A vertice visae ellipticae, polis rotundatis, tumore utrobique saepe manifesto. Long. cell., 120–138 μ ; lat. cell., 42–43 μ ; lat. isthm., 16 μ ; lat. tumor., 16–17 μ ; crass., 21 μ.

Sample 246 (not uncommon).

This variety, in the shape of its semicells in front view (Fig. 9, *A*),
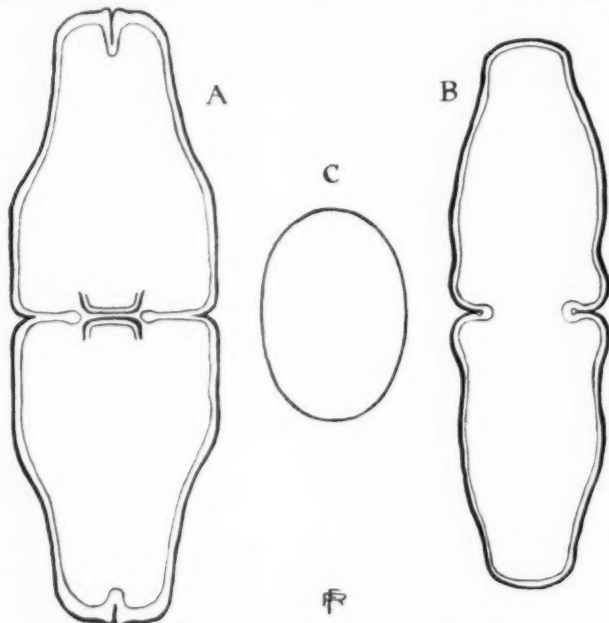
Fig. 9.—*Euastrum brasiliense,* Borge, var. *africanum,* Fritsch and Rich, n. var. *A,* front-, *B,* side-, and *C,* end-views. × 700.

has a greater resemblance to a form of the species figured by Borge (*cf.* Arkiv f. Bot., xv, 1918, p. 60, Pl. V, fig. 5) than to the type itself. It however differs from all described forms of *E. brasiliense* in the relatively greater length, the square character of the rather wide central protuberances (which resemble those of *E. gnathophorum,* W. & G. S. West), and the flat truncate apices. The type and the variety differ from all the other species of the *ansatum*-group in possessing but a single median protuberance on either side of the semicell. Compare also with *E. huillense,* W. & G. S. West.

2. *Euastrum elegans* (Bréb.), Kuetz.; W. & G. S. West, *op. cit.,* ii, 1905, p. 48, Pl. XXXVIII, figs. 16–21.

Var. *symmetricum*, Fritsch and Rich, nov. var. (Fig. 10).

E. subparvum, circiter 1½ plo longius quam latum, profunde constrictum, sinu angusto-lineari, extus non ampliato. Semicellulae ovato-pyramidatae, angulis basalibus subrectangularibus, marginibus lateralibus crenis duabus ab apice et basi et inter se fere aequidistantibus, partibus interpositis late concavis ; apicibus incisura profunda aperta plus quam tertiam partem
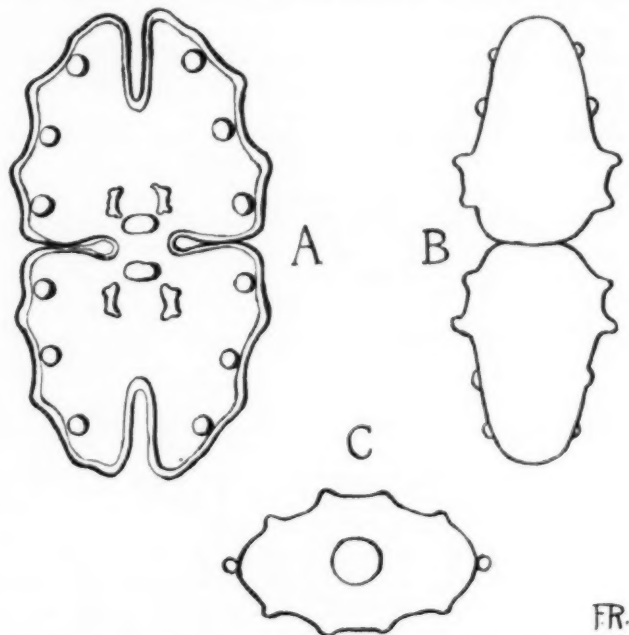
FIG. 10.—*Euastrum elegans* (Bréb.), Kuetz., var. *symmetricum*, Fritsch and Rich, n. var. *A*, front-, *B*, side-, *C*, end-views. × 1800.

longitudinis semicellulae ; tumore granulato in medio semicellularum supra isthmum et granulis parvis singulis intra excavationem quamque marginum lateralium. A latere visae ovatae, apice rotundato, et tumore emarginato utrobique paullo supra isthmum. A vertice visae ellipticae granulo parvo in utroque polo et granulis 4 fere aequidistantibus in utraque margine. Zygosporae globosae, aureo-fuscae, spinis acuminatis densis munitae.

Long. cell., 35–41 μ ; lat. cell., 21–26 μ ; lat. isthm., 7–8 μ ; crass., 12–13 μ ; lat. zygosp. (sine spin.), 28 μ.

Sample 246 (rare).

The distinguishing features of this variety are the symmetrical distribution of the two crests on the lateral margins and of the three intramarginal granules in front-view, and the symmetrical outline in end-view. The apical incision is also much deeper than is the rule in the type. On the other hand the side-view is very much like that of a typical *E. elegans*. In Fig. 17 in Messrs. West's monograph the crests on the lateral margins show an approximation to the symmetrical arrangement characteristic of the variety here described.

Only a limited number of individuals were observed, and we are consequently unable to say whether the ornamentation of the semicells is always
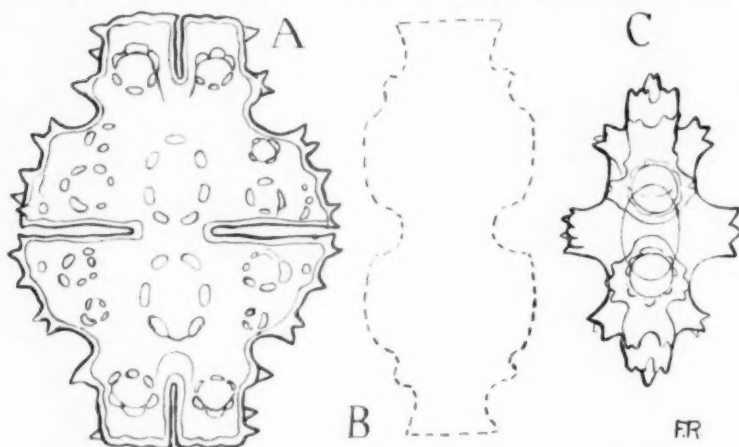
Fig. 11.—*Euastrum incertum*, Fritsch and Rich.   *A*, front-, *B*, side-, and *C*, oblique end-views.   × 1100.

exactly like that shown in the figure. The zygospore was unfortunately lost before it could be drawn.

3. *Euastrum incertum*, Fritsch and Rich, n. sp. (Fig. 11).

E. mediocre, circiter 1½ plo longius quam latum, profunde constrictum, sinu lineari paullum aperto. Semicellulae a fronte visae subpyramidatae, partibus lateralibus inferioribus convexis dentibus parvis in margine vel intra marginem munitis; lobo polari subbrevi, a parte inferiore semicellulae incisura lata vadosa discreto, marginibus lateralibus subparallelis dentibus munitis, dente prominenti in angulo apicali utroque, apice truncato incisura profunda angustissima; tumore magno granulato in media semicellularum supra isthmum et tumoribus minoribus granulatis 3 intra marginem lateralem utramque, granulis varie dispositis in superficie reliqua. A latere visae (?) plus minus ovatae, marginibus fere deplanatis, apice

truncato exserto. A vertice visae ellipticae tumore granulato prominenti utroque, polis dentatis.

Long. cell., 60 μ ; lat. cell., 44–46 μ ; lat. isthm., 9–10 μ ; crass., 28 μ.
Sample 246 (very rare).

This species comes nearest to *E. bidentatum*, Naeg., of which it is possibly only a variety. In the form of the front-view (Fig. 11, *A*) there is considerable resemblance to fig. 17 on Pl. XXXVII of Messrs. West's monograph, but the lower lateral margins are not bilobulate, the apex is flat and truncate, and the apical teeth are horizontal ; moreover, the ornamentation of the cell is of a much more elaborate type. Apart from the median granulated tumour, there are three other smaller ones situated on either side of the semicell, one within the basal angle, another within the apical angle, and a third opposite the incision separating the polar lobe from the lower part of the semicell. We do not feel altogether sure of the characters of the side- and end-views, as very few specimens were seen. It seems, however, that the central granulated protuberance projects far more pronouncedly than in *E. bidentatum*, and we have also obtained the impression that the side-view has more flattened edges. The new species may also be compared with some forms of *E. evolutum*, W. & G. S. West.

Genus MICRASTERIAS Agardh.

1. *Micrasterias bewsii*, Fritsch and Rich, n. sp. (Fig. 12).

M. mediocris, circiter 1½ plo longior quam lata, profunde constricta, sinu aperto acutangulo, extremo paullum contracto, interdum dente parvo munito. Semicellulae a fronte visae pyramidato-trapeziformes, angulis basalibus acuto-rotundatis, dentibus 3–4 instructis, marginibus lateralibus inferioribus valde convergentibus et dentibus acutis plus minus numerosis praeditis ; lobo polari valde dilatato, lateribus late concavis glabris, apice subtruncato dentibus acutis, prope angulos apicales exsertos densioribus, munito. In superficie semicellularum costis duabus paullum curvatis dentatis, a margine isthmi primordiam lobi polari attingentibus, et costis minus effiguratis intra marginem partis basalis semicellulae. A latere visae ovatae marginibus convexis, apice acuto, dentibus diverse dispositis munitae. A vertice non visae.

Long. cell., 114–120 μ ; lat. cell., 87–90 μ ; lat. isthm., 21–23 μ ; lat. lob. pol. ad apic., 65 μ ; crass., 22 μ.

Sample 246 (very rare).

Although we have seen very few specimens of this form, and cannot pronounce quite certainly on some of the details, we have no hesitation in describing it as a new species, since it appears quite distinct from any

other *Micrasterias.* The only species at all resembling it is *M. urniformis,*
W. & G. S. West (Trans. Linn. Soc., Bot., vi, 1901, p. 157, Pl. XX, fig.
19), in which, however, the shape of the semicells is decidedly different,
there are no superficial toothed ridges, the number of teeth is far less,
and the dimensions are about one-half. There is also some resemblance
to a form figured by Borge (Arkiv f. Bot., xv, 1918, p. 69, Tab. VI, fig. 1)
under the name of *M. tropica,* Nordst., var. *indivisum* (Nordst.), Eichl. &
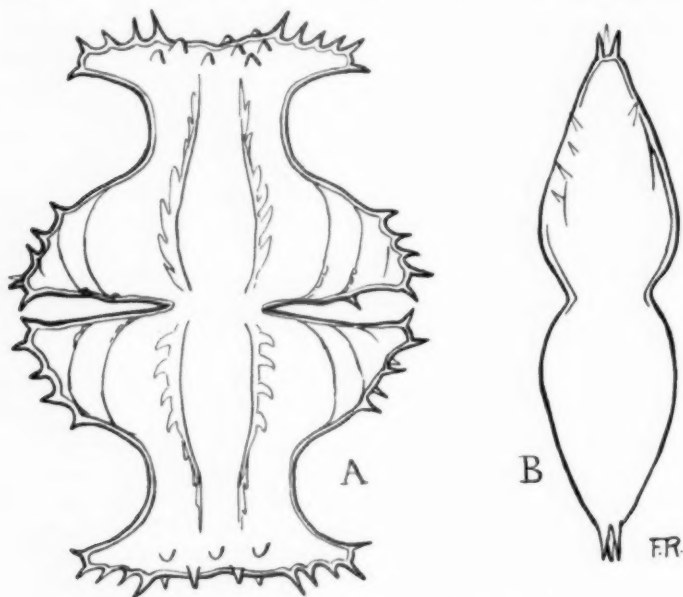
FIG. 12.—*Micrasterias bewsii,* Fritsch and Rich, n. sp. *A,* front-,
and *B,* side-views. × 700.

Racib. This, however, appears to differ rather markedly from *M. euas-
troides,* Joshua, var. *indivisa,* Nordst. (K. Sv. Vet.-Akad. Handl., xxii,
1888, No. 8, p. 31, Tab. II, fig. 17) in the more marked production of the
polar lobe, the truncate apex, and the absence of the central tumour, and
should probably be regarded as a distinct variety.

We have not been able to make out quite clearly the details of ornamenta-
tion of the surface of the semicells of *M. bewsii.* It appears, however,
that, apart from the two prominent toothed ridges extending from the
outer edge of the isthmus to the base of the polar lobe, there are several
other similar, though less developed, ridges situated between the principal

ones and the basal angles. There would also appear to be a number of teeth, on either side, within the apex of the semicell (*cf.* Fig. 12).

2. *Micrasterias decemdentata* (Naeg.), Arch.; Naegeli, Gatt. einzell. Algen, 1849, p. 123, Tab. VI, H, fig. 2.

Formae diversae (Fig. 13). Long. cell., 83–93 μ; lat. cell., 93–105 μ. Sample 246 (not uncommon).

The individuals present varied much among one another with respect to the number of teeth developed at the margins of the lobes; moreover, there was often asymmetry as regards this feature between the two sides
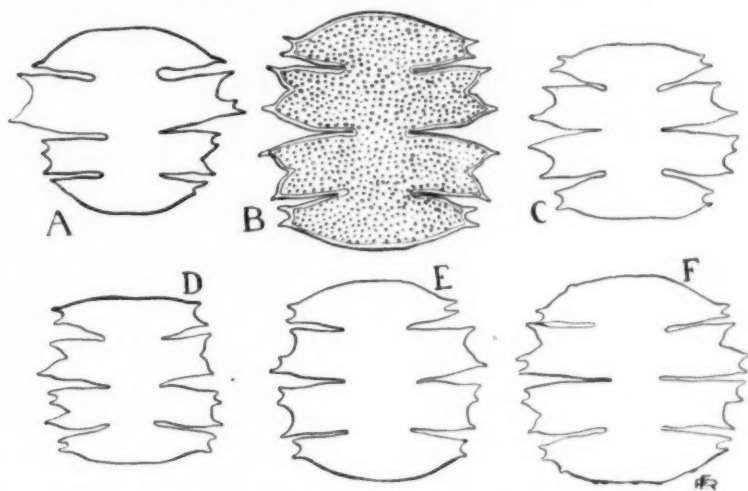
Fig. 13.—*Micrasterias decemdentata* (Naeg.), Arch., diverse forms. × 350.

of the semicell (*cf.* Fig. 13, *A, C, E*). The figures will suffice to illustrate these points. In the individual shown in Fig. 13, *F*, there was a tendency towards the differentiation of further teeth on the apices of the semicells. Attention should also be drawn to the fact that the apices were more markedly rounded than in Naegeli's original figure or in most of those that have been published subsequently. Moreover, the cells were always shorter than they were broad.

3. *Micrasterias denticulata*, Bréb.; W. & G. S. West, *op. cit.*, ii, p. 105, Pl. XLIX, figs. 1–7, Pl. L, figs. 1, 2.

Sample 246 (very rare).

Long. semicell., 126 μ; lat. cell., 212 μ.

Var. *angusto-sinuata*, Gay; W. & G. S. West, *op. cit.*, ii, p. 108, Pl. L, fig. 5.

Forma incisuris inter lobulis principalibus minus profundis.   Long. cell., 210–270 μ ;   lat. cell., 138–156 μ ;   lat. isthm., 24–30 μ (Fig. 14, *A*).

Sample 246 (not uncommon).

4. *Micrasterias truncata* (Corda), Bréb. ;   W. & G. S. West, *op. cit.*, ii, p. 82, Pl. XLII, figs. 1–8.

Var. *africana*, Fritsch and Rich, nov. var. (Fig. 14, *B* and *C*).

Differt a typo incisuris inter lobum polarem et lobos laterales superiores praeruptioribus, incisuris per totam semicellulam plerumque profundioribus,
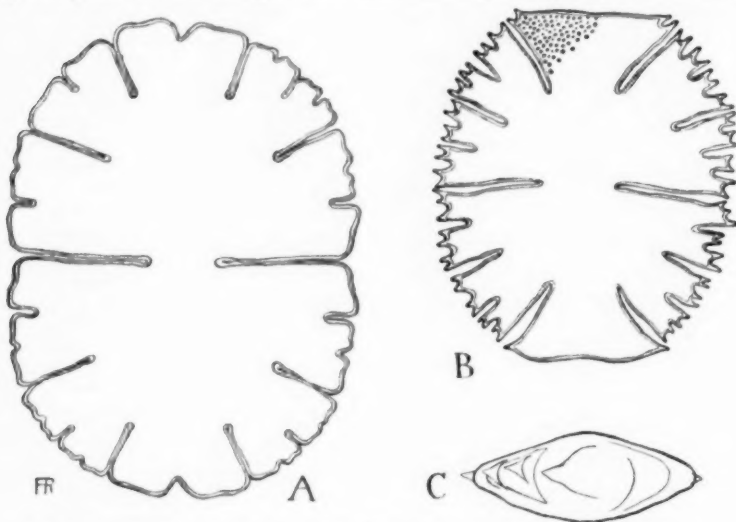
Fig. 14.—*A, Micrasterias denticulata*, Bréb., var. *angusto-sinuata*, Gay, forma, × 350.   *B* and *C, M. truncata* (Corda), Bréb., var. *africana*, Fritsch and Rich, n. var.   *B*, front-view, × 320.   *C*, somewhat oblique end-view, × 320.

marginibus lateralibus convexioribus ita ut in aspectu verticali series plures lobulorum manifestae sunt.   Lobus polaris late cuneatus, lobi laterales diverse divisi, membrana punctata.

Long. cell., 125–158 μ ;   lat. cell., 100–144 μ ;   lat. isthm., 18–30 μ ; lat. lob. pol. ad apic., 66–75 μ ;   crass., 46–47 μ.

Samples 246 (not uncommon), 253 (rather rare).

This form is sharply distinguished from the type as figured in Messrs. West's monograph.   The angle formed by the incisions between the polar and upper lateral lobes with the transverse plane varies somewhat, and extreme cases show a trend in the direction of *M. rotata* (Grev.), Ralfs, which, however, differs in several other striking respects.   Great diversity was noticed among the different individuals in the form of the apical

margin of the polar lobe and in the degree of incision and the teething of the lateral lobes, in which respects the new variety shows a tendency parallel to that of the type (*cf.* G. S. West, Journ. Linn. Soc., Bot., xxvii, 1899, p. 383, Pl. IX, figs. 9–16 ; and Groenblad, Acta Soc. Fauna et Flora Fennica, xlix, 1921, No. 7, p. 21, Pl. I, figs. 4, 5, 8, 11).

A form of this species has been recorded from Madagascar.

GENUS COSMARIUM CORDA.

1. *Cosmarium bewsii*, Fritsch and Rich, n. sp. (Fig. 15).

C. mediocre, circiter 1½ plo longius quam latum, profunde constrictum,
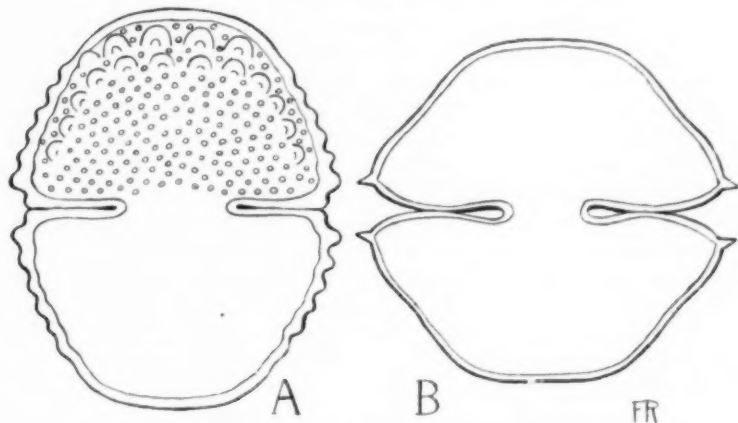
FIG. 15.—*A*, *Cosmarium bewsii*, Fritsch and Rich, n. sp., front-view. *B*, *C. maximum* (Boerges.), W. & G. S. West, forma. *A* × 1000 ; *B* × 500.

sinu angusto-lineari introrsum leviter dilatato, membrana crassa. Semicellulae ovato-pyramidatae e basi lata, angulis basalibus subrectangularibus, lateribus convexis tuberculis rotundatis 3–4 supra basim (ubi membrana praecipue incrassata est) et ulterius undulationibus exiguis paucis, apice subtruncato, angulis apicalibus rotundatis ; intra apicem tuberculis rotundatis solidis vel leviter cavis in seriebus 2–3 transversis, et intra marginem lateralem tuberculis similibus in serie unica (?). Tota superficies semicellulae granulis (poris ?) parvis rotundatis aequidistantibus munita. A vertice et a latere non visae. Chromatophorae axilares pyrenoidibus duabus in quaque semicellula.

Long. cell., 59–60 *μ* ; lat. cell., 40–45 *μ* ; lat. isthm., 13 *μ*.

Sample 246 (rare).

We have described this as a new species, in spite of not having seen either end- or side-views, since it is unlike any *Cosmarium* that has hitherto become known. The tubercles, which are solid or slightly hollow rounded projections of the thick cell-wall, show a peculiar and very characteristic disposition. The only species with which this one might be compared is *C. askenasyi*, Schmidle (Hedwigia, xxxiv, 1895, p. 304, Tab. IV, fig. 7), which, however, shows many points of difference.

2. *Cosmarium binum*, Nordst.; W. & G. S. West, *op. cit.*, iii, p. 246, Pl. LXXXVIII, figs. 10–14.

Samples 244 and 246 (rather rare).

Long. cell., 60–66 μ; lat. cell., 42–48 μ; lat. isthm., 13–15 μ; crass., 30–33 μ.

Whilst the shapes of the front- and end-views quite agreed with those of *C. binum*, the granulation of the central region of the semicells was not quite typical. The median tumour bore vertical rows of rather small granules, thus resembling more that of *C. subspeciosum*, Nordst., var. *validius* than that of *C. binum*; moreover, the series of rounded granules above the isthmus was not always clearly recognisable, though quite distinct in some specimens (*cf.* the form described and figured by Borge, Arkiv f. Bot., xv, No. 13, 1918, p. 38, Tab. III, fig. 19). It is obvious that, in discriminating between *C. binum* and the forms of *C. subspeciosum*, the shape of the front-view must play as important a rôle as the nature of the central tumour.

3. *Cosmarium boeckii*, Wille; W. & G. S. West, *op. cit.*, iii, p. 234, Pl. LXXXVI, figs. 26–32.

Samples 242, 262, 269, 277 (rare).

Long. cell., 24–30 μ; lat. cell., 21–27 μ; lat. isthm., 8 μ.

In view of our having seen no empty specimens this determination is a little uncertain.

4. *Cosmarium capense*, De Toni, Sylloge algarum, etc., i, 1899, p. 969. (Syn.: *C. pyramidatum*, Bréb., subsp. *capense*, Nordstedt, Act. Univ. Lund, xvi, 1880, p. 6, Tab. I, fig. 8.)

Forma ad var. *minor*, Fritsch (Ann. S. Afr. Mus., ix, p. 550, fig. 26) valde accedens, sed marginibus lateralibus vel in aspectu frontali vel in aspectu laterali plus rotundatis. Long. cell., 35–39 μ; lat. cell., 27 μ; lat. isthm., 7 μ.

Sample 246 (very rare).

Evidently frequent in South Africa.

5. *Cosmarium constrictum*, Delponte, Mem. Acad. Torino, ser. II, xxx, 1878, p. 3, Tab. VII, figs. 13–15.

Forma minor. Long. cell., 17–22 μ; lat. cell., 12–15 μ; lat. isthm., 5–6 μ; isthmo minus aperto (Fig. 16, *B*).

Samples 246, 272 (rare).

This small *Cosmarium* is probably best regarded as a form of Delponte's species. Probably *C. inane*, Turner (K. Sv. Vet. Akad. Handl., xxv, No. 5, 1892, p. 57, Tab. VIII, fig. 41) also belongs to this species.

6. *Cosmarium cucurbita*, Bréb.; W. & G. S. West, *op. cit.*, iii, p. 106, Pl. LXXIII, figs. 31–33.

Forma *latior*, W. & G. S. West, *loc. cit.*, p. 108, Pl. LXXIV, fig. 1.

Sample 246 (rather rare).

Long. cell., 42 μ; lat. cell., 26 μ.

Var. *attenuatum*, G. S. West, Journ. Bot., xlii, 1904, p. 286, Pl. 464, fig. 18; W. & G. S. West, *op. cit.*, iii, p. 108, Pl. LXXIII, figs. 34–36. (Syn.: *C. conicum*, W. & G. S. West, Trans. Linn. Soc., Bot., v, 1895, p. 71, Pl. VIII, fig. 12.)

Sample 246 (not uncommon).

Long. cell., 30–35 μ; lat. cell., 17–21 μ; lat. isthm., 16–17 μ.

There does not appear to be any decisive point of distinction between *C. conicum* and the variety *attenuatum* of *C. cucurbita* (*cf.* also Fritsch, Ann. Biol. lacustre, vii, 1914, p. 49, and Schmidle, Nuov. Notarisia, ser. viii, 1897, p. 70). The variety *brevius* of *C. conicum* described by Gutwinski (Bull. Acad. Sci. Cracovie, 1909, p. 452, Pl. VII, fig. 16) seems to be much the same as the forma *latior* of *C. cucurbita*. Various individuals were seen in our material connecting var. *attenuatum* with the forma *latior*, although in many specimens the one or other type is clearly recognisable.

Both the type and var. *attenuatum* have been found in Madagascar.

7. *Cosmarium cucurbitinum* (Biss.), Luetkemueller, Verhandl. k. k. Zool.-Bot. Ges. Wien, 1905, p. 337. (Syn.: *Penium cucurbitinum*, Biss.; W. & G. S. West, *op. cit.*, i, p. 94, Pl. IX, figs. 13, 14.)

Var. *subpolymorphum*, Nordst.; W. & G. S. West, *loc. cit.*, p. 95, Pl. IX, figs. 19, 20.

Sample 295 (rather rare).

Long. cell., 75–84 μ; lat. cell., 35–41 μ.

8. *Cosmarium gayanum*, De Toni; W. & G. S. West, *op. cit.*, iv, p. 7, Pl. CIII, figs. 5, 6.

Var. *rotundata*, F. E. Fritsch, Trans. Roy. Soc. S. Africa, ix, 1921, p. 43, fig. 18.

Forma saepe longior, granulis frequentioribus et in seriebus verticalibus dispositis. Long. cell., 67–75 μ; lat. cell., 38–49 μ; lat. isthm., 12–18 μ; crass., 28 μ.

Samples 246 (rare), 253 (rare), 262 (rare), 303 (rare), 305 (not uncommon), 468 (rather rare).

Many of the individuals agreed in the shape of their front-view entirely with the figure of var. *rotundata* above cited, but others were proportionally

longer, thus approaching more to the shape of the type. All of these, except for occasional individuals that had a slight flattening of the apex on one or other semicell, possessed the rounded apices typical of the variety.

9. *Cosmarium granatum*, Bréb.; W. & G. S. West, *op. cit.*, ii, p. 186, Pl. LXIII, figs. 1–4.

Var. *africanum*, F. E. Fritsch, Trans. Roy. Soc. S. Africa, ix, 1921, p. 32, fig. 11, *C*.

Samples 276, 305 (in both cases very rare).

Long. cell., 29–33 μ; lat. cell., 19–21 μ; lat. isthm., 4, 5–6 μ. The majority of the individuals were of the form shown in fig. 11, *C, a'* (*loc. cit.*).

This variety was first described from Kentani.

10. *Cosmarium hammeri*, Reinsch; W. & G. S. West, *op. cit.*, ii, p. 181, Pl. LXII, figs. 20, 21.

Forma minor, lateribus superioribus vix retusis, apicibus late truncatis, membrana indistincte punctata. Long. cell., 38–41 μ; lat. cell., 34–36 μ; lat. isthm., 10–11 μ; crass., 16 μ.

Sample 253 (rare).

Forma minor, aut typica, aut lateribus superioribus apicibusque vix retusis, paene rectis. Long. cell., 29–33 μ; lat. cell., 21–25 μ; lat. isthm., 5–7 μ. (Fig. 16, *A*.)

Sample 246 (common).

Both these forms seem to have a simple elliptical end-view. In sample 246 some of the individuals had a front-view with the perfectly typical outline of the type, but others showed scarcely any retuseness of the upper lateral margins or apex. In some cases the apex was truncate or even slightly convex (*cf.* var. *africanum*, Fritsch). In sample 253 all the individuals, though larger, showed these peculiar characteristics. *Cf. forma* Borge, Bih. K. Sv. Vet.-Akad. Handl., xxvii, Afd. iii, No. 10, 1901, p. 24. The typical form of this species is known from Kentani.

11. *Cosmarium holmiense*, Lund.; W. & G. S. West, *op. cit.*, iii, p. 1, Pl. LXV, figs. 1, 2.

Sample 273 (rare).

A form of this species has been previously recorded from Table Mountain.

12. *Cosmarium javanicum*, Nordstedt, Act. Univ. Lund, xvi, 1880, p. 7, Tab. I, fig. 10.

Var. *profundo-constrictum*, Fritsch and Rich, nov. var. (Fig. 17, *A–D*).

Differt a typo isthmo multo angustiore, marginibus lateralibus superioribus plerumque leviter concavis, angulis basalibus saepe leviter protrusis; apice semicellulae rotundato truncato, raro subretuso. Chromatophorae parietales pyrenoidibus pluribus quam in typo. Membrana in totam

superficiem grosse punctata. Long. cell., 102–166 μ ; lat. cell., 51–83 μ ; lat. isthm., 18–24 μ ; crass., 45 μ.

Sample 246 (not uncommon).

A few individuals agreed almost exactly with Nordstedt's figure of the type, except for the much deeper constriction and a slightly broader and flatter apex (Fig. 17, *B*). The majority, however, showed the slight con-
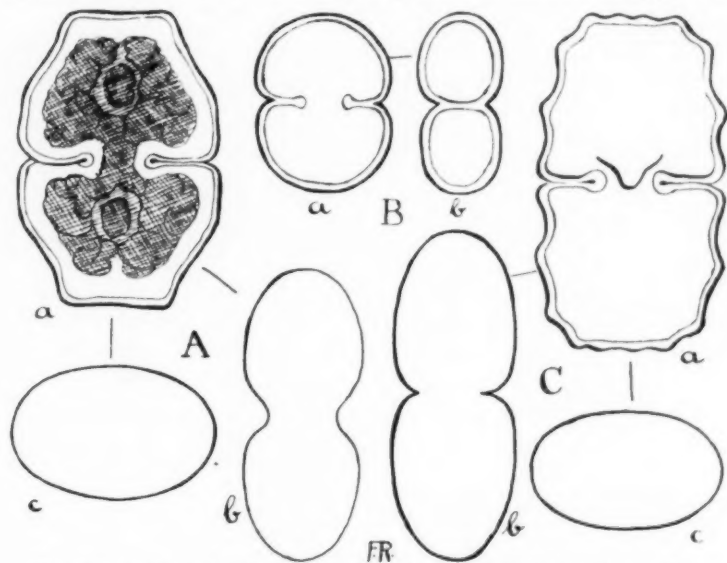
FIG. 16.—*A, Cosmarium hammeri,* Reinsch, forma ; *a,* front-, *b,* side-, and *c,* end-views (× 1000). *B, C. constrictum,* Delp., forma ; *a,* front-, and *b,* side-views (× 1500). *C, C. tetragonum,* Naeg., var. *bipapillata,* Eichl. ; *a,* front-, *b,* side-, and *c,* end-views (× 1500).

cavity of the upper lateral margins mentioned in the diagnosis (*cf.* Fig. 17, *A*), and many had somewhat protruded basal angles.

C. maculatum, Turner (K. Sv. Vet.-Akad. Handl., xxv, No. 2, 1892, p. 49, Tab. VII, fig. 31) is very closely allied to *C. javanicum,* Nordst., but differs in the character of the sinus and the greater convexity of the lateral margins. Its chloroplasts are unknown. Schmidle (Hedwigia, xxxiv, 1895, p. 301, Tab. IV, figs. 3, 4) has described a *Cosmarium (Pleurotaeniopsis) maculatiforme* from Sumatra, which Messrs. West (Trans. Linn. Soc., Bot., vi, 1901, p. 163) have regarded as synonymous with *C. maculatum.* It is, however, more likely, in view of its type of constriction, that it is a form of *C. javanicum,* Nordst. It is interesting to note that Schmidle speaks of the depth of constriction varying considerably.

C. maculatum var. *major*, Gutwinski (Bull. internat. Acad. sc. Cracovie, No. 9, 1902, p. 588, Pl. XXXVII, fig. 27) should doubtless be referred to *C. javanicum* and is probably the same as Schmidle's form, though larger.

13. *Cosmarium laeve*, Rabh.; W. & G. S. West, *op. cit.*, iii, p. 99, Pl. LXXIII, figs. 8, 9.

Long. cell., 16–19 μ; lat. cell., 12–13 μ; lat. isthm., 4 μ.
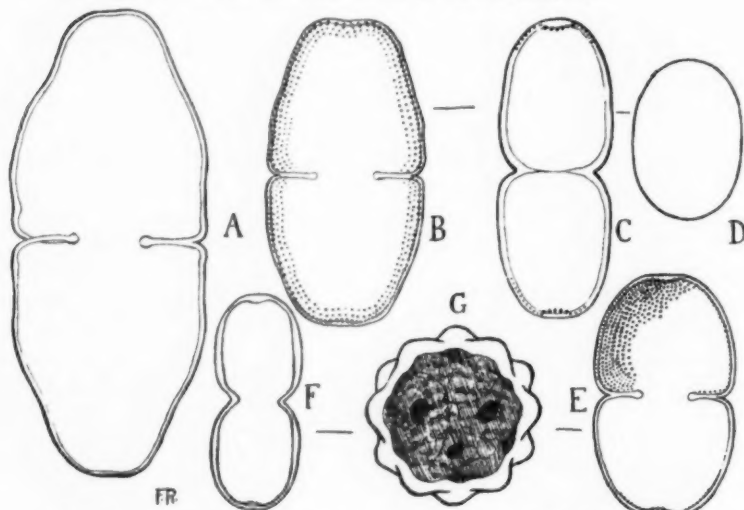
Fig. 17.—*A–D*, *Cosmarium javanicum*, Nordst., var. *profundo-constrictum*, Fritsch and Rich, n. var. : *A* and *B*, front-views of two individuals; *C*, side-view; *D*, end-view. *E–G*, *C. pseudopyramidatum*, Lund. var. *maximum*, Boerges., forma : *E*, front-view; *F*, side-view; *G*, zygospore. *A* × 500, *B–D* × 400, *E–G* × 450.

Sample 246 (common).

Long. cell., 30–33 μ; lat. cell., 20–22 μ; lat. isthm., 6–7 μ.

Samples 239, 242 (rather common).

In sample 246 the individuals were quite typical; in the other two samples a number belonged to f. *rotundata* (cf. Fritsch, Trans. Roy. Soc. S. Africa, ix, 1921, p. 35).

This species is evidently widely distributed in South Africa.

14. *Cosmarium lundellii*, Delp.; W. & G. S. West, *op. cit.*, ii, p. 138, Pl. LVII, figs. 1, 2.

Var. *corruptum* (Turner), W. & G. S. West, *loc. cit.*, p. 139, Pl. LVII, figs. 5, 6. (Syn. : *C. corruptum*, Turner, K. Sv. Vet.-Akad. Handl., xxv, No. 2, 1892, p. 51, Tab. VIII, fig. 2.)

Sample 246 (rather common).

Long. cell., 31–42 μ ; lat. cell., 39–42 μ ; lat. isthm., 20–22 μ ; crass., 25 μ.

With respect to the shape of the front-view our specimens on the whole agreed better with Turner's figures (*loc. cit.*) than with those in Messrs. West's monograph. They never showed so well-defined a truncate apex as is there depicted, in fact some specimens were almost rounded at the summit. Our dimensions practically agree with those of f. *minor*, Gutwinski (Sprawoz. Kom. Fizyogr. Ak. Umiej. Krakow, xxx, 1895, p. 88, Tab. III, fig. 19), which, however, seems to stand nearer to *C. lundellii*, Delp. as figured by Messrs. West than to *C. corruptum*.

This variety has already been recorded from Madagascar.

15. *Cosmarium mansangense*, W. & G. S. West, Ann. Roy. Bot. Gard., Calcutta, vi, 1907, p. 209, Pl. XIV, fig. 15.

Var. *africanum*, Fritsch and Rich, nov. var. (Fig. 18, *D* and *E*).

Semicellulae a fronte visae formae ejusdem quam in typo, sed $1\frac{1}{2}$–2 plo majores constrictione profundiore ; membrana crassa, chromatophoris parietalibus pyrenoidibus pluribus ; verrucis membranae a superficie visis circularibus vel rectangularibus, in sectione opticali visis apicibus deplanatis vel emarginatis, ca. 32 in ambitu semicellulae et ca. 18 series verticales in aspectu frontali. Long. cell., 91–124 μ ; lat. cell., 35–45 μ ; lat. isthm., 27 μ.

Sample 246 (not uncommon).

The chloroplasts of *C. mansangense* were not described in the original diagnosis, but there can be no doubt that the variety here established belongs to this species and that the latter will prove to possess the same parietal chloroplasts.

16. *Cosmarium margaritiferum*, Menegh. ; W. & G. S. West, *op. cit.*, iii, p. 199, Pl. LXXXIII, figs. 4–11.

Var. *exsertum*, Fritsch and Rich, nov. var. (Fig. 18, *A–C*).

Marginibus lateralibus semicellularum convexis, cum incisura manifesta tertia parte ab apice, ita ut tertia pars superior cujusque semicellulae exserta videtur ; apice lato truncato ; granulis aequalibus plus minusve verticaliter dispositis, granulo quoque punctis 6 regulariter dispositis circumdato. Aspectus lateralis typo similis est ; aspectus verticalis in medio leviter inflatus. Long. cell., 39–45 μ ; lat. cell., 35–36 μ ; lat. isthm., 11–12 μ ; crass., 22 μ.

Sample 246 (not uncommon).

This is a very well-marked form characterised by the incision found about one-third of the way down from the apex (Fig. 18, *A*), the vertical arrangement of the granules, and the fact that the minute punctae around them are not confined to the central region of the semicell. We cannot,

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however, say certainly whether these punctae extend to the extreme margin of the latter.

17. *Cosmarium maximum* (Boerges.), W. & G. S. West, Journ. Bot., 1897, p. 114. (Syn.: *C. obsoletum* (Hantzsch), Reinsch, subsp. *maximum*,
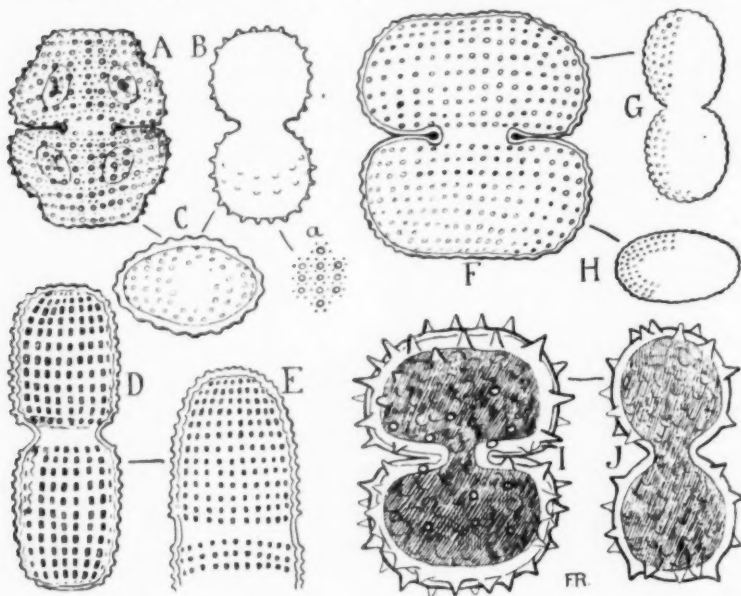
Fig. 18.—*A–C, Cosmarium margaritiferum*, Menegh., var. *exsertum*, Fritsch and Rich, n. var.; *A*, front-, *B*, side-, and *C*, end-views. × 700. *D–E, C. mansangense*, W. & G. S. West, var. *africanum*, Fritsch and Rich, n. var.; *D*, front-, and *E*, side-views. × 400. *F–H, C. pseudobroomei*, Wolle, var. *compressum*, G. S. West, forma; *F*, front- (× 650), *G*, side-, and *H*, end-views. × 400. *I–J, C. trachypleurum*, Lund., var. *natalensis*, Fritsch and Rich, n. var.; *I*, front-, and *J*, side-views. × 500.

Boergesen, Vidensk. Medd. Nat. Foren. Kjøbenhavn, 1890, p. 42, Tab. VI, fig. 37.)

Forma latior et minor. Long. cell., 97–99 μ; lat. cell., 105–111 μ; lat. isthm., 18 μ (Fig. 15, *B*).

Sample 246 (rare).

The specimens agreed altogether with those figured by Boergesen (*loc. cit.*), except as regards dimensions and the relation of length to breadth. They showed the same slight retuseness of the middle of the lateral margins, and it appears that this feature is distinctive of the type, although not evident in var. *minor*, W. & G. S. West (*loc. cit.*, p. 114, Tab. 367, fig. 21).

18. *Cosmarium obtusatum*, Schmidle ; W. & G. S. West, *op. cit.*, iii, p. 7, Pl. LXV, figs. 13, 14. (Syn. : *C. ochhodes*, Nordst., var. *obtusatum*, Gutwinski, Bot. Centralbl., xliii, 1890, p. 68 ; Sprawozd. kom. fizyogr. Akad. Umiej. Krakowie, czesc. II, xxvii, 1892, p. 51, Tab. II, fig. 3.)

Sample 246 (rare).

Long. cell., 91–96 μ ; lat. cell., 71–75 μ ; lat. isthm., 18–22 μ.

Large specimens agreeing in dimensions with those originally described by Gutwinski. This species is widely distributed in Africa.

19. *Cosmarium pachydermum*, Lund. ; W. & G. S. West, *op. cit.*, ii, p. 139, Pl. LVII, fig. 7.

Var. *aethiopicum*, W. & G. S. West, *op. cit.*, p. 140, Pl. LVII, figs. 8, 9. (Syn. : *C. lundellii*, Delp., var. *aethiopicum*, W. & G. S. West, Journ. Bot., 1897, p. 114.)

Forma major. Long. cell., 120–129 μ ; lat. cell., 100–105 μ ; lat. isthm., 40–42 μ ; scrobiculis membranae bene evolutis.

Samples 253, 282 (rare).

20. *Cosmarium pseudobroomei*, Wolle ; W. & G. S. West, *op. cit.*, iv, p. 22, Pl. C, figs. 7–8, Pl. CIII, fig. 7.

Var. *compressum*, G. S. West, Journ. Linn. Soc., Bot., xxxviii, 1907, p. 123, Pl. VII, fig. 11.

Forma paullo longior quam latior, lateribus plus minusve rotundatis. Long. cell., 42–57 μ ; lat. cell., 40–52 μ ; lat. isthm., 12 μ ; crass., 30 μ (Fig. 18, *F–H*).

Samples 242, 246, 262, 272, 276, 468, 470 (never common).

We have referred these forms to the var. *compressum*, since in the majority of the individuals the length was only very slightly greater than the breadth and the lateral margins in front-view were rounded in the way shown in West's figures. Borge has described a form of the species from South America (Arkiv f. Bot., i, 1903, p. 87, Tab. II, fig. 13), which comes very close to some of the specimens observed by us, although smaller. The two may well be identical and nearly related to var. *compressum*. G. S. West has recorded the latter from the Cazengo District of Angola.

21. *Cosmarium pseudopyramidatum*, Lund. ; W. & G. S. West, *op. cit.*, ii, p. 201, Pl. LXIV, figs. 9–12.

Sample 246 (common).

Long. cell., 43–57 μ ; lat. cell., 25–32 μ ; lat. isthm., 10–12 μ.

Previously recorded from Madagascar.

Subsp. *maximum*, Boergesen, Botany of the Faeroes, i, 1901, p. 222, Pl. VII, fig. 8.

Forma minor, area paullo incrassata in media semicellula supra isthmum, apicibus semicellularum plerumque rotundatis, interdum leviter deplanatis vel etiam subretusis, punctis membranae manifestissimis. Long. cell.,

75–90 μ; lat. cell., 45–57 μ; lat. isthm., 14–18 μ; crass., 35–38 μ (Fig. 17, *E–G*).

Sample 246 (common).

This is a very well-marked form, intermediate in many respects between Boergesen's subspecies *maximum* and Nordstedt's "*forma major excavata*" (K. Sv. Vet.-Akad. Handl., xxii, No. 8, 1888, p. 54, Tab. VI, fig. 1). In the shape of the semicells (*cf.* Fig. 17, *E*) it approaches nearer to the former, in dimensions it comes nearer to the latter. The thickening of the membrane in the region above the isthmus, plainly evident in side- and end-views (Fig. 17, *F*), is invariably recognisable. Nordstedt's and Boergesen's figures show the same feature, but no mention of it is made in the text in either case. In our specimens the basal angles of the semicells were almost invariably rounded. The punctation of the membrane appears to be due to a kind of pitting of the wall, rather than to granulation (*cf.* Fig. 17, *E*).

The majority of the individuals showed one pyrenoid per semicell, but there were occasionally two, either only in one or in both semicells. Such cases render a distinction between *C. pyramidatum* and *C. pseudo-pyramidatum* very difficult. Messrs. West state in their monograph (*loc. cit.*, p. 202) that the two species differ in size and in the number of pyrenoids in the chloroplasts. Since, however, Luetkemueller (Oesterr. Bot. Zeitschr., xliii, 1893, Tab. II, figs. 1–7) has figured individuals of *C. pyramidatum*, Bréb., with a varying number of pyrenoids (1–5) per semicell, these distinctions fall away. The type-forms of the two species are different enough, but it is evident that they are connected with one another by numerous transitional forms.

Globose or broadly elliptical zygospores (Fig. 17, *G*) were seen in sample 246 agreeing with those of *C. pseudopyramidatum*, Lund., except for their larger dimensions (diam., 60–75 μ). It can hardly be doubted that they belong to the form just described.

22. *Cosmarium punctulatum*, Bréb.; W. & G. S. West, *op. cit.*, iii, p. 206, Pl. LXXXIV, figs. 13, 14.

Samples 246, 295, 305, 309 (in all cases rather rare).

Long. cell., 33–36 μ; lat. cell., 29–34 μ; lat. isthm., 9 μ; crass., 17 μ.

Already known from various parts of South Africa.

23. *Cosmarium sexangulare*, Lund.; W. & G. S. West, *op. cit.*, iii, p. 81, Pl. LXXII, fig. 3.

Forma *minutissima*, nov. form.

In aspectu frontali typo similis est, sed multo minor; in aspectu verticali elliptico polis rotundatis. Long. cell., 13 μ; lat. cell., 11 μ; lat. isthm., 3, 5 μ.

Sample 246 (rare).

The type has so far not been recorded from South Africa.

24. *Cosmarium tetragonum*, Naeg.; W. & G. S. West, *op. cit.*, iii, p. 17, Pl. LXVI, figs. 20, 21.

Var. *bipapillata*, Eichler, Pamiet. Fizyogr. Warszawa, xiv, 1896, Dzial iii, Tab. III, fig. 17. (Fig. nostr. 16, *C.*)

Sample 246 (rather rare).

Long. cell., 34–37 μ; lat. cell., 19, 5–24 μ; lat. isthm., 5 μ.

Several of the semicells were more rectangular than is the case with those figured by Eichler and thus approached nearer to the type (Fig. 16, *C, a*). The lateral undulations are rather more marked than in the type, both in our and Eichler's specimens, and occasional individuals showed a very faint undulation of the apex. Eichler's form should probably have varietal value.

Borge (Bot. Notiser, 1913, p. 20, Tab. I, fig. 17) has described and figured a form of var. *lundellii*, Cooke, which would seem more appropriately referred to var. *bipapillata*, Eichler; it agrees with the latter in all essential respects, whilst it does not show the protracted apex of the former. There can be little doubt that forma *tatrica*, Raciborski (Pamiet. Akad. Umiej. Krakow, xvii, 1890, p. 80, Pl. V, fig. 11), is a form of this variety in which the papillae were poorly developed or absent. *Cf.* also *C. trilobulatum*, Reinsch, var. *basichondrum*, Nordst., which would perhaps be better regarded as a form of *C. tetragonum* var. *bipapillata*.

The type has been recorded by Nordstedt from the Cape.

25. *Cosmarium trachypleurum*, Lund.; W. & G. S. West, *op. cit.*, iii, p. 172, Pl. LXXXI, figs. 2, 3.

Var. *natalensis*, Fritsch and Rich, nov. var. (Fig. 18, *I–J*).

Var. major, angulis basalibus subquadratis, spinis bene efformatis, paucis in margines laterales, pluribus intramarginalibus et sparsis in totam superficiem semicellulae, apice truncato sine spinis sed spinis intramarginalibus munito. Aspectus lateralis quam in typo, aspectus verticalis non visus. Area centralis granulata supra isthmum incerta. Long. cell., 67–77 μ; lat. cell., 48–57 μ; lat. isthm., 14–16 μ; crass., 37 μ.

Sample 246 (rare).

This should be compared with var. *spinosum*, W. & G. S. West (Trans. Linn. Soc., Bot., v, 1895, p. 66, Pl. VII, fig. 17), from which it differs in its much larger dimensions and in the presence of pronounced spines just within the apex of the semicell (Fig. 18, *I*). Very few of the spines are situated on the margins, the majority forming a well-defined outer and a less regular inner series within the margins. As we saw no empty semicells, it has been impossible to make out clearly the details of the central granulated area.

26. *Cosmarium trilobulatum*, Reinsch; W. & G. S. West, *op. cit.*, ii, p. 185, Pl. LXII, figs. 28–30.

Forma lobis apicalibus latioribus, marginibus lateralibus inferioribus interdum subretusis. Long. cell., 19–21 μ; lat. cell., 11–13 μ; lat. lob. apic., 8–11 μ; lat. isthm., 2–3 μ.

Samples 239 (rare), 246 (common).

The type has been recorded by Schmidle from various parts of Africa.

Genus ARTHRODESMUS Ehrenberg.

1. *Arthrodesmus triangularis*, Lagerh.; W. & G. S. West, *op. cit.*, iv, p. 97, Pl. CXIV, figs. 11–13.

Forma *minor*, G. S. West, Journ. Linn. Soc., Bot., xxxix, 1909, p. 66.

Sample 289 (rare).

Long. cell., 19 μ; lat. cell. c. spin., 39 μ.

Genus STAURASTRUM Meyen.

1. *Staurastrum alternans*, Bréb.; W. & G. S. West, *op. cit.*, iv, p. 170, Pl. CXXVI, figs. 8, 9.

Sample 246 (not uncommon).

Long. cell., 32–34 μ; lat. cell., 30–31 μ; lat. isthm., 9–10 μ.

The majority of the individuals failed to show the customary twisting at the isthmus, resulting in alternation of the two semicells when seen in end-view. A doubtful zygospore was found, but the empty semicells were intermingled with débris and their specific identity could not be established. The spore in question was globose, 30 μ in diameter, and covered with short spines, the surface being areolate. It did not show the forked spines mentioned in Ralfs' description of the zygospore (Brit. Desm., 1848, p. 133), but, as Messrs. West have pointed out (*loc. cit.*, p. 172), there is some doubt as to whether Ralfs really found the zygospore of this species. The latter has been recorded from Madagascar and a form from Little Namaqualand.

2. *Staurastrum sebaldi*, Reinsch, Algenfl. mittl. Teil. v. Franken, 1867, p. 175, Pl. XI, fig. 1.

Var. *altum* (Boldt), W. & G. S. West, Trans. Linn. Soc., Bot., v, 1896, p. 267. (Syn.: *S. proboscideum*, Arch., var. *altum*, Boldt, Oefvers. Sv. Vet.-Akad. Foerhandl., 1885, No. 2, p. 117, Tab. VI, fig. 34.)

Forma minor, semicellulae a vertice visae spinis bicuspidatis intra margines frequentioribus et plus regulariter dispositis, marginibus subconcavis. Lat. sine spin., 44–55 μ; lat. c. spin., 49–60 μ; long., 49–59 μ; lat. isthm., 11–12 μ (Fig. 19).

Sample 246 (rather common).

Our form agreed more closely with that described and figured by Nordstedt (K. Sv. Vet.-Akad. Handl., xxii, No. 8, 1888, p. 36, Tab. IV, fig. 5) than with the form of Boldt (*loc. cit.*). The corners of the semicells

were little protruded, a fact which was especially evident in the end-view (Fig. 19, *B*), the edges of which were very slightly concave. The markings on the face of the semicell nearest to the isthmus agreed very well with those shown in Nordstedt's fig. 5, *d*, but the distal face bore more numerous and more regularly arranged bicuspid teeth than in his fig. 5, *b* ; moreover, they formed in their entirety a more markedly concave group.

There can be no doubt that this and Nordstedt's form diverge somewhat from Boldt's variety and approach nearer to *S. sebaldi*, Reinsch. It may be that a further study of these forms will show that they would best be removed from Boldt's var. *altum* and that the latter should remain under
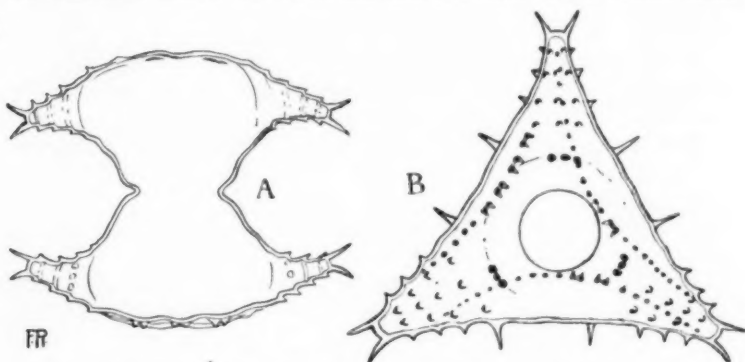
FIG. 19.—*Staurastrum sebaldi*, Reinsch, var. *altum* (Boldt), W. & G. S. West, forma *minor*. *A*, front-, and *B*, slightly oblique end-view, showing the markings both on the external face of the semicell and on that adjacent to the isthmus. × 800.

S. proboscideum, Arch., with which it certainly shows some resemblances differentiating it from *S. sebaldi*, Reinsch. Unfortunately, Boldt's figure of the front-view is not altogether clear and not quite in agreement with the end-view. This fact, and the rather scanty material we had for investigation, have led us for the present to adopt the current synonymy. The characters of *S. sebaldi* itself are not at all clearly established ; *cf.* for instance the figures given by Migula (Kryptogamenfl., vi, 1907, Pl. XXVII, *E*, fig. 3), Ducellier (Bull. Soc. Bot. Genève, 1916, p. 73, fig. 61), and Messrs. West (*loc. cit.*, Pl. XVIII, figs. 2, 3).

3. *Staurastrum trihedrale*, Wolle, Desm. Unit. States, 1884, p. 123, Pl. XL, figs. 12, 13 ; W. & G. S. West, Trans. Linn. Soc., Bot., v, 1896, p. 260, Pl. XVI, fig. 29.

Sample 246 (rare).

Long. cell., 46 μ ; lat. cell., 31 μ ; lat. isthm., 10 μ.

This species has been recorded from Madagascar.

Genus HYALOTHECA Ehrenberg.

1. *Hyalotheca dissiliens* (Smith), Bréb. ;   Ralfs, Brit. Desm., 1848, p. 51, Tab. I, fig. 1.

Sample 246 (common, with zygospores).

Lat. cell., 24–30 μ.

A form of this species has been found in Madagascar.

(3) ZYGNEMACEAE.

Genus SPIROGYRA Link.

1. *Spirogyra decimina* (Muell.), Kuetz. ;   Petit, *Spirogyra* d. env. d. Paris, 1880, p. 25, Pl. VIII, figs. 1–3 ;   Borge, Zygnemales, in Suesswasserfl. Deutschlands, etc., ix, 1913, p. 27, fig. 32.

Forma *tropica*, G. S. West, Journ. Linn. Soc., Bot., xxxviii, 1907, p. 106.

Sample 237.

Crass. cell. veget., 52–54 μ ;   long. zygosp., 74–80 μ ;   lat. zygosp., 49–54 μ.

The cells were in most cases only three times as long as wide.   These broader tropical forms of *S. decimina*, with three chloroplasts in the cell, approach rather closely *S. neglecta* (Hass.), Kuetz., the most important point of difference being the slight inflation of the fructifying cells in the latter case.   *S. decimina* is a species widely distributed in Africa.

2. *Spirogyra inflata* (Vauch.), Rabenh. ;   Petit, *op. cit.*, p. 7, Pl. I, figs. 4–6 ;   Borge, *op. cit.*, p. 17, fig. 3.

Sample 239.

Crass. cell. veget., 21–22 μ ;   lat. zygosp., 31–35 μ, 2–3 plo longior.

3. *Spirogyra longata* (Vauch.), Kuetz. ;   Petit, *op. cit.*, p. 20, Pl. V, figs. 4, 5 ;   Borge, *op. cit.*, p. 25, fig. 26.

Samples 264, 270.

Crass. cell. veget., 33–36 μ ;   long. zygosp., 56–66 μ ;   lat. zygosp., 35–38 μ.

4. *Spirogyra neglecta* (Hass.), Kuetz. ;   Petit, *op. cit.*, p. 26, Pl. IX, figs. 1–5 ;   Borge, *op. cit.*, p. 29, fig. 36.

Forma cellulis fructiferis evidenter inflatis, zygosporis eas fere complentibus et interdum fere sphaericis (Fig. 20, *A* and *B*).

Crass. cell. veget., 52–54 μ ;   crass. cell. fructif., 68 μ ;   long. × lat. zygosp., 96 × 99, 93 × 67, 90 × 64, 90 × 60, 83 × 67, 74 × 67, 72×64 μ.

Sample 251.

Var. *pseudoternata*, Fritsch and Rich, nov. var. (Fig. 20, *C*).

Cellulis vegetativis diametro 1½–2½ plo longioribus, in media parte non inflatis ; chromatophoris 3, anfractibus 1½–2, pyrenoidibus magnis conspicuis ; cellulis fructiferis valde inflatis, abbreviatis ; zygosporis sphaericis vel plerumque ellipticis, rarius cellulas complentibus, saepe transverse vel oblique dispositis. Lat. cell. veget., 40–48 μ ; lat. cell. fructif., 72–74 μ ; long. × lat. zygosp., 74 × 48, 64 × 38, 64 × 43, 56 × 42 μ.

Sample 262.

Fructifying threads of this variety show considerable resemblance to
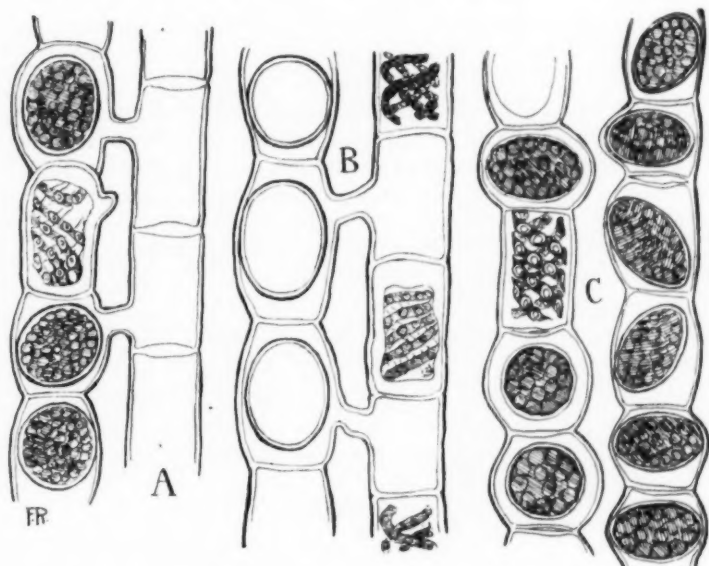
Fig. 20.—*A* and *B*, *Spirogyra neglecta* (Hass.), Kuetz., forma. *C*, *S. neglecta* (Hass.), Kuetz., var. *pseudoternata*, Fritsch and Rich, nov. var. × 200.

those of *S. ternata* (Ripart), Petit (*op. cit.*, p. 26, Pl. VIII, figs. 4–7), which many algologists regard as a variety of *S. neglecta.* The vegetative threads, however, are of even width throughout and thus fail to show what appears to us to be the outstanding characteristic of *S. ternata* in the vegetative condition. It seems very doubtful whether the special type of chloroplast upon which Petit lays emphasis, both for *S. neglecta* and *S. ternata*, is likely to be more than a nutritive (possibly starvation) condition.

(NOTE.—Sterile, and therefore indeterminable, material of *Spirogyra* was also found in samples 219, 229, 235, 241, 242, 257, 261, 262, 266, 267, 268, 269, 271, 272, 276, 277, 292, 300, 304, 305, and 309.)

Genus SIROGONIUM Kuetzing.

(Syn. : *Choaspis* Gray.)

1. *Sirogonium sticticum,* Kuetz. ; Petit, *op. cit.,* p. 34, Pl. VII, figs. 6–8. (Syn. : *Spirogyra stictica* (Engler bot.), Wille ; Borge, *op. cit.,* p. 32, fig. 47.)

Forma zygosporis plerumque subsphaericis. Crass. cell. veget., 50–60 μ ; long. × lat. zygosp., 77 × 74, 77 × 70, 74 × 58, 70 × 54, 64 × 64 μ.

Sample 253.

Genus ZYGNEMA Agardh.

1. *Zygnema pectinatum* (Vauch.), Ag. ; Borge, *op. cit.,* p. 33, fig. 49. Sample 229.

This species has already been recorded from Kentani.

(Note.—Sterile filaments of species of this genus occurred more or less abundantly in samples 246, 272, 282, 288, 296, and 299. In 246 a number of the cells showed the contents contracted into a small spherical mass of about the same width as the cell (18–19 μ), but leaving the greater part of the length empty. These contracted protoplasts still showed clearly the two pyrenoids, and were surrounded by a thin smooth membrane. No doubt they represented an incipient resting-stage.)

(4) MESOCARPACEAE.

No fertile material of members of this family was observed, but sterile filaments of *Mougeotia* (possibly in part belonging to *Debarya*) were more or less abundant in samples 242, 261 (a narrow form, 9 μ wide), 262, 269, 276, and 468.

II. HETEROKONTAE.

(4) TRIBONEMACEAE.

Genus OPHIOCYTIUM Naegeli.

1. *Ophiocytium cochleare* (Eichw.), A. Braun ; Heering, Suess-wasseralg. Schleswig-Holsteins, etc., i, 1906, *loc. cit.,* p. 121, fig. 26.

Samples 241, 257 (rare).

Already recorded from Cape Colony.

Genus TRIBONEMA Derbès et Solier.

1. *Tribonema bombycinum,* Derbès et Solier ; Heering, *op. cit.,* p. 131, fig. 36. (Syn. : *Conferva bombycina,* Ag.)

Forma *minor,* Wille.

Samples 243, 255, 257 (not common).

Already recorded from Cape Colony.

(5) BOTRYDIACEAE.

Genus BOTRYDIUM Wallroth.

1. *Botrydium granulatum* (L.), Grev. ; Heering, *op. cit.*, p. 145, fig. 43. Sample 289.

Some of the individuals exhibited cyst-formation in the branches of the rhizoid-system, the cysts being produced in a single row and being of rather uneven size. Their mature appearance strongly suggested that they were formed by a thickening of the walls of the rhizoids, followed by the ingrowth of numerous septa cutting up the protoplasm into a number of separate fragments. The walls and septa were clearly stratified. This method of development is not in agreement with that usually described and figured (*cf. e.g.* Oltmanns, Morph. u. Biol. d. Alg., i, 1904, pp. 26, 27), according to which the protoplasm, which has passed into the rhizoids from the overground vesicle, divides into a number of parts, each of which becomes surrounded by a membrane of its own. The method here described is similar to that by means of which the *Gongrosira*-condition of certain species of *Vaucheria* is attained.

Messrs. West (Journ. Bot., 1897, p. 235) have established a var. *aequinoctiale* of this species from Loanda. This variety is, however, only characterised by its small dimensions (" circiter tertia pars dimensionis plantae typicae "), and it may be doubted whether a difference of this kind warrants the establishment of a separate form.

III. CYANOPHYCEAE (MYXOPHYCEAE).

(*a*) CHROOCOCCALES.

(1) CHROOCOCCACEAE.*

Genus CHROOCOCCUS Naegeli.

1. *Chroococcus cohaerens* (Bréb.), Naegeli, Gatt. einzell. Algen, 1849, p. 46 ; Lemmermann, Algen, Kryptogamenfl. d. Mark Brandenburg, 1910, p. 55.

Sample 231 (not uncommon).

Already recorded by Reinsch from the Cape.

2. *Chroococcus turgidus* (Kuetz.), Naegeli, *op. cit.*, p. 46 ; Lemmermann, *op. cit.*, p. 53.

Sample 295 (very rare).

Diam. colon. 2-cell., 25–26 μ.

Already recorded from various parts of South Africa.

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* A species of *Aphanocapsa*, in insufficient quantity for determination, occurred in sample 296.

Genus GLOEOCAPSA Kuetzing.

1. *Gloeocapsa alpina* (Naeg.), Brand emend., Bot. Centralbl., lxxiii,
p. 22 ; Lemmermann, *op. cit.*, p. 67.

Samples 298 (?), 302, and 308.

2. *Gloeocapsa caldariorum*, Rabenhorst, Fl. Europ. Alg., ii, p. 37 ;
Lemmermann, *op. cit.*, p. 63.

Samples 231 and 232 (not uncommon).

3. *Gloeocapsa punctata*, Naegeli, *op. cit.*, p. 51, Tab. I, *F*, fig. 6 ; Lem-
mermann, *op. cit.*, p. 64.

Sample 305.

There was no indication of stratification in the sheaths of any of our
specimens.

4. *Gloeocapsa rupestris*, Kuetzing, Tab. Phycol., i, p. 17, Tab. XXII,
fig. 2.

Sample 302.

5. *Gloeocapsa sanguinea*, Kuetzing, Phyc. gen., p. 174 ; Lemmermann,
op. cit., p. 66.

Samples 294, 308.

(Note.—Indeterminable material of *Gloeocapsa* was also observed in
samples 246, 305, 309, and 310.)

Genus MERISMOPEDIA Meyen.

1. *Merismopedia glauca* (Ehrenb.), Naegeli, *op. cit.*, p. 55, Tab. I, *D*,
fig. 1 ; Lemmermann, *op. cit.*, p. 85.

Sample 275 (not common).

Already recorded from various parts of South Africa.

Genus MICROCYSTIS Kuetzing.

1. *Microcystis aeruginosa*, Kuetzing, Tab. Phyc., i, p. 6, Tab. VIII ;
Lemmermann, *op. cit.*, p. 75. (Syn. : *Clathrocystis aeruginosa* (Kuetz.),
Henfrey.)

Sample 246 (not uncommon).

Genus ONCOBYRSA C. A. Agardh.

1. *Oncobyrsa rivularis* (Kuetz.), Menegh. ; Kuetzing, Tab. Phycol., i,
Tab. XXXII, fig. 2 ; Lemmermann, *op. cit.*, p. 89.

Sample 293.

(b) CHAMAESIPHONALES.

(1) CHAMAESIPHONACEAE.

GENUS CHAMAESIPHON BRAUN AND GRUNOW.

1. *Chamaesiphon incrustans*, Grun.; Rabenhorst, Fl. Europ. Alg., ii, 1865, p. 149; Lemmermann, *op. cit.*, p. 99.

Sample 293 (on *Chantransia*).

Previously recorded from the Orange Free State and Kentani.

(c) HORMOGONEALES.

(1) OSCILLATORIACEAE.

GENUS OSCILLATORIA VAUCHER.

1. *Oscillatoria brevis*, Kuetz.; Gomont, Monogr. d. Oscillariées, Ann. Sci. nat., sér. 7, xvi, 1893, p. 229, Pl. VII, figs. 14, 15; Lemmermann, *op. cit.*, p. 115.

Sample 222.

The threads did not show any of the inflated cells commonly found in this species, but were otherwise quite typical. They were collected together in a compact stratum. This species is already known from Kentani.

2. *Oscillatoria formosa*, Bory; Gomont, *op. cit.*, p. 230, Pl. VII, fig. 16; Lemmermann, *op. cit.*, p. 116.

Samples 217 (as a dense stratum on *Phormidium tenue*), 242.

Diam. trich., 5–6 μ.

This species is very close to *O. brevis*, differing chiefly in the greater length of the cells, the occasional slight constriction between them, and the blunter tips. It has already been recorded from various parts of South Africa.

3. *Oscillatoria geminata*, Menegh.; Gomont, *op. cit.*, p. 222, Pl. VII, fig. 6; Lemmermann, *op. cit.*, p. 112.

Sample 216 (together with *O. tenuis*, the latter more abundant).

Previously recorded from Kentani.

4. *Oscillatoria irrigua*, Kuetz.; Gomont, *op. cit.*, p. 218, Pl. VI, figs. 22, 23; Lemmermann, *op. cit.*, p. 111.

Samples 252, 261, 266, 267, 268, 272, 275, and 276.

Diam. trich., 7, 5–11 μ.

5. *Oscillatoria limosa*, Agardh; Gomont, *op. cit.*, p. 210, Pl. VI, fig. 13: Lemmermann, *op. cit.*, p. 108.

Samples 220 (rather common) and 261 (rare).

Diam. trich., 13–16 μ.

Previously known from various parts of South Africa.

6. *Oscillatoria princeps*, Vaucher; Gomont, *op. cit.*, p. 206, Pl. VI, fig. 9; Lemmermann, *op. cit.*, p. 109.

Sample 218 (rare).

Diam. trich., 14 u.

Already recorded from the Karoo and Kentani.

7. *Oscillatoria tenuis*, Ag.; Gomont, *op. cit.*, p. 220, Pl. VII, figs. 2, 3; Lemmermann, *op. cit.*, pp. 91, 110.

Samples 216, 252, 261, 272, and 277.

Diam. trich., 6–9 μ.

Widely distributed in South Africa.

Genus SPIRULINA Turpin.

1. *Spirulina major*, Kuetz.; Gomont, *op. cit.*, p. 251, Pl. VII, fig. 29; Lemmermann, *op. cit.*, pp. 91, 120.

Samples 252 and 270.

Widely distributed in South Africa.

Genus PHORMIDIUM Kuetzing.

1. *Phormidium autumnale*, Gomont, *op. cit.*, p. 187, Pl. V, figs. 23, 24; Lemmermann, *op. cit.*, p. 132.   (Syn.: *P. uncinatum*, Gom.)

Samples 247 and 266 (in the latter fragments only).

Already recorded from Cape Colony.

2. *Phormidium retzii*, Gomont, *op. cit.*, p. 175, Pl. V, figs. 6–9; Lemmermann, *op. cit.*, p. 127.

Sample 263.

3. *Phorimidium tenue*, Gomont, *op. cit.*, p. 169, Pl. IV, figs. 23–25; Lemmermann, *op. cit.*, p. 125.

Samples 217, 222.

Already recorded from various parts of South Africa.

4. *Phormidium valderianum*, Gomont, *op. cit.*, p. 167, Pl. IV, fig. 20; Lemmermann, *op. cit.*, p. 126 (sub *P. valderiae* (Delp.), Schmidle).

Sample 252 (?).

Since only small fragments of the stratum were present, the determination is uncertain.   The species is already known from Cape Colony.

(Note.—Indeterminable material of this genus was also encountered in sample 248.)

Genus LYNGBYA Agardh.

1. *Lyngbya aerugineo-coerulea* (Kuetz.), Gomont, *op. cit.*, p. 146, Pl. IV, figs. 1–3 ; Lemmermann, *op. cit.*, p. 141.

Samples 219 and 273.

This species has already been recorded from Cape Colony.

2. *Lyngbya mucicola*, Lemmermann, *op. cit.*, p. 137. (Syn. : *L. gloio-phila*, Lemmermann, Abh. Nat. Ver. Bremen, xvi, 1900, p. 355, Tab. II, fig. 36.)

Sample 232 (within the stratum of *Nostoc humifusum*).

3. *Lyngbya versicolor* (Wartm.), Gomont, *op. cit.*, p. 147, Pl. IV, figs. 4, 5 ; Lemmermann, *op. cit.*, p. 138.

Sample 225.

Genus DASYGLOEA Thwaites.

1. *Dasygloea amorpha*, Berkely ; Gomont, *op. cit.*, Ann Sci. nat., sér. 7, xv, 1893, p. 347, Pl. XIII, figs. 11, 12 ; Lemmermann, *op. cit.*, pp. 102, 104.

Var. *africana*, Fritsch and Rich, nov. var. (Fig. 21, *F*).

Vaginae filorum seniorum luteo-fuscae per omnes partes, plerumque distincte lamellatae, apice non in laciniis diviso ; trichomatibus saepe singulis intra vaginam, apicibus plerumque rotundatis vel interdum attenuatis ; alioqui typo similis est.   Diam. fil., 40–45 μ ; diam. trich., 3, 5–4 μ.

Sample 284.

This variety is chiefly characterised by the prominent stratification of the sheaths of the older filaments (Fig. 21, *F*), which assume a uniform yellowish-brown tint, not extending only to the outer part as is described for the type.   Other differences from the latter lie in the absence of the characteristic laciniae into which the sheaths of the type often divide at their tips (*cf.* Gomont's fig. 11), the frequent presence of only one trichome within the sheath, and the usual absence of any attenuation at the apices of the trichomes.

Genus MICROCOLEUS Desmazières.

1. *Microcoleus annulatus*, Fritsch and Rich, n. sp. (Fig. 21, *A–E*).

M. terrestris, fila in limo humido sparsim repentia, parce ramosa. Vaginae crassae firmae cylindraceae, passim constrictionibus exiguis crebris munitae, quae in partes quasdem tantum frequentiores sunt ut constrictiones successivae annulares oriuntur ; vaginae filorum juniorum saepe distincte lamellatae, eae filorum seniorum non lamellatae margine interiore obscuro.   Trichomata aeruginosa, intra vaginam saepe permulta, arcte congesta paullum inflexa sed interdum subparallela, ad genicula

haud constricta ; apice sublonge attenuato, acuto vel interdum capitato ; articuli subquadrati vel diametro paullo breviores ; dissepimenta frequenter granulata.

Lat. trich., 4–6 μ ; lat. fil., usque ad 50 μ.
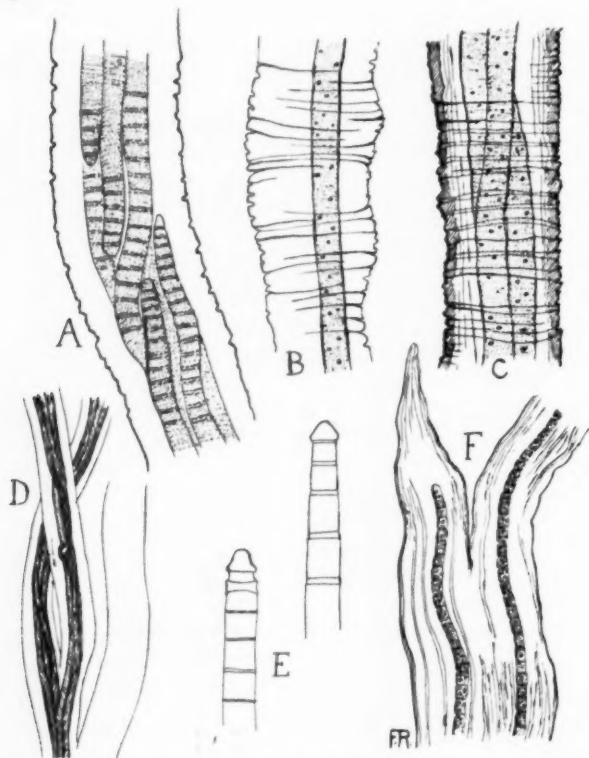
Sample 289.

Fig. 21.—*A–E, Microcoleus annulatus*, Fritsch and Rich, n. sp.   *D* shows a small part of the stratum, *A–C*, parts of the threads, and *E*, the apices of two trichomes (*A–C* and *E* × 700 ; *D* × 200).   *F, Dasygloea amorpha*, Berkely, var. *africana*, Fritsch and Rich, n. var. (× 400).

This species shows much resemblance to *M. vaginatus* (Vauch.), Gom., from which it is chiefly distinguished by the characters of its sheath.   The latter is more sharply defined, at least in the young filaments, than is usually the case in this genus, and its inner limit is often clearly recognisable. Moreover, it is often distinctly stratified, the boundary-lines of the strata not being straight but generally more or less crinkled (Fig. 21, *C*).   The

most striking feature, however, lies in the frequent annular constriction of the cylindrical sheath. The constrictions are distributed quite irregularly, but at certain points they follow so closely upon one another as to give the sheaths a very characteristic transversely striated appearance (Fig. 21, *B–C*). A similar feature has been recorded for *M. aitchisonii*, Schaar-schmidt (Koezlemenyek Magyar Tudomanyos Akad. Budapest, xviii, 1884, p. 241, fig. 1), but here the constrictions appear at regular intervals, and the species also differs from that here described in other respects. The possibility cannot be overlooked that the peculiar features of the sheath may be the result of the action of the preservative (formalin) ; this does not, however, seem very probable and could be settled by the investigation of fresh material. In older filaments, though the constrictions are still evident, the stratification and the firm inner boundary of the sheath are no longer recognisable (Fig. 21, *A*).

The apices of the trichomes were attenuated in nearly every case, but only in relatively few of them could a specially developed conical apical cell with calyptra be recognised (Fig. 21, *E*). This is again a point of differ-ence from *M. vaginatus*. Abundant hormogone-formation was taking place.

2. *Microcoleus vaginatus* (Vauch.), Gomont, *op. cit.*, p. 355, Pl. XIV, fig. 12 ; Lemmermann, *op. cit.*, pp. 102, 156.

Sample 288 (rather rare).

Genus SCHIZOTHRIX Kuetzing.

1. *Schizothrix epiphytica*, Fritsch, n. sp. (Fig. 22).

S. terrestris, fila epiphytica, angustissima, vulgo 6–10 μ crassa, calce non indurata, fila speciei *Stigonema* circumvoluta vel per eas crescentia, interdum fasciculos erectos formantia ; fila elongata flexuosa, passim in laciniis divisa et pseudoramosa. Vaginae roseae, passim hyalinae, firmae, non lamellosae ambitu subirregulares. Trichomata pallide aeruginosa, intra vaginam pauca, subparallela, saepe approximata, in ramulis plerumque singula, ad genicula haud constricta, 1–1, 5 μ lata ; articuli diametro longiores, 4 ad 5 μ longi, protoplasmate grosse granuloso sparsim farcti ; cellula apicalis non attenuata, obtusa.

Sample 294 * (epiphytic on *Stigonema* spp., common).

This species is essentially characterised by its epiphytic habit, the usually very narrow filaments, and the crimson colour of the sheaths. The bulk of the filaments that are found entwining or growing closely adpressed and parallel to the threads of species of *Stigonema* (Fig. 22, *A*)

* This is the same as Bews' No. 105. The same form occurs also in Bews' No. 104, which is not included in the present series of samples.

are exceedingly narrow, rarely exceeding 8 μ in diameter, and frequently measuring less ; such filaments enclose usually only one or two trichomes (Fig. 22, *B*, *C*).   The older basal portions, which are rarely properly decipherable among the tangle of *Stigonema* may, however, be considerably wider, as much as 15–20 μ, and enclose several of the same narrow trichomes. Branching (Fig. 22, *B*) seems to occur profusely in the lower parts of the plant.   The sheaths are usually uniformly red, but here and there rare hyaline stretches occur, and not uncommonly one side of the sheath is colourless and the other tinted ; it seems probable that these hyaline
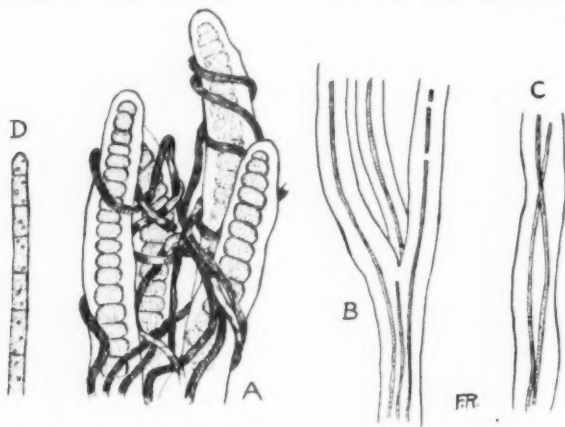
FIG. 22.—*Schizothrix epiphytica*, Fritsch, n. sp.   *A*, general habit, showing the method of growth on *Stigonema* (× 300).   *B* and *C*, parts of two threads enlarged (× 700).   *D*, single trichome (× *ca*. 1600).

portions are those which are not directly exposed to the light.   The rôle of this form in the colonisation of bare rock-surfaces is described in the Journal of Ecology, iv, 1916, p. 132 (*cf.* also the introduction, p. 301).

Among the species of the section *Chromosiphon*, none have so far been described possessed both of such narrow trichomes and of red-coloured sheaths.   In the small dimensions there is resemblance to *S. delicatissima*, W. & G. S. West, and *S. antarctica*, Fritsch (Rep. Brit. Antarct. (" Terra Nova ") Exped., 1910, Bot., i, 1917, p. 11, Pl. I, figs. 21–24).

2. *Schizothrix fuscescens*, Kütz. ; Gomont, *op. cit.*, p. 324, Pl. XI, figs. 4–6 ; Lemmermann, p. 152.

Forma trichomatibus angustioribus, vaginis vel luteis vel luteo-fuscis vel hyalinis.   Lat. trich., 1·5–2 μ.

Sample 306 (forming upright tufts arising from a basal tangle, partly colonised by *Calothrix braunii*, forma).

We believe this form is best classed under the above species, although differing from the current descriptions in several particulars. Especially in the interior of the stratum the sheaths were colourless; when pigmented they were more commonly of some shade of yellow than brown. Many of the trichomes were filled with large highly refractive granules, obscuring the septa.

3. *Schizothrix muelleri*, Naegeli; Gomont, *op. cit.*, p. 322, Pl. X, figs. 5–7; Lemmermann, *op. cit.*, p. 152.

Sample 294 (rare).

Crass. trich., 6, 5–7 μ.

(Indeterminable material of *Schizothrix* also occurred in sample 254.)

(2) NOSTOCACEAE.

Genus NOSTOC Vaucher.

1. *Nostoc ellipsosporum* (Desmaz.), Rabenhorst, Fl. Europ. Alg., ii, p. 169; Bornet et Flahault, Revis. d. Nostoc. hétérocyst., Ann. Sci. nat., Bot., sér. 7, 1888, p. 198; Lemmermann, *op. cit.*, p. 167.

Sample 260 (disorganising fragments among *Anthoceros*).

Crass. trich., 3, 5–4 μ; lat. spor., 5 μ; long. spor., 8, 5–9 μ.

The dimensions of the spores were considerably less than usual, in spite of the fact that they must have been mature, as the thallus was in a state of disorganisation. The elliptico-cylindrical cells and heterocysts, however, would seem to indicate that the material belonged to this species. Some of the spores were slightly curved.

2. *Nostoc humifusum*, Carm.; Bornet et Flahault, *op. cit.*, p. 201; Lemmermann, *op. cit.*, p. 168.

Sample 232 (together with *Gloeocapsa caldariorum*).

The material was quite typical, except that no sheaths were discernible around the individual filaments. Such sheaths appear also to be lacking in var. *fluitans*, W. & G. S. West (Ann. Roy. Bot. Gard., Calcutta, vi, 1907, p. 240, Pl. XII, figs. 27, 28). The stratum was at many points interwoven with the threads of *Lyngbya mucicola*, Lemm.

3. *Nostoc microscopicum*, Carm.; Bornet et Flahault, *op. cit.*, p. 210; Lemmermann, *op. cit.*, p. 170.

Sample 295 (?).

In view of the absence of spores and the not quite typical character of the material, this determination is a little uncertain, although we have no doubt that it constitutes a form of this species. The sheaths were distinct only in the outer part of the colony, were yellow-brown in colour, and slightly constricted between the individual cells, giving the sheaths an

intestiform appearance. The cells (crass., 4–5 μ) were much depressed, almost discoid, and only about half as long as broad. The heterocysts were spherical, 7–8 μ wide.

(NOTE.—Young, or otherwise undeterminable, material of *Nostoc* was also met with in samples 245, 273, 274, 303, 305, and 309.)

GENUS ANABAENA BORY.

Material of this genus was present in samples 246 and 296, but not in the right condition for determination. In 296 two species, a wider and a narrower one, were present, the latter possibly being *A. inaequalis* (Kuetz.), Born. and Flah.; only two spores were however seen.

GENUS CYLINDROSPERMUM KUETZING.

1. *Cylindrospermum alatosporum*, F. E. Fritsch, Ann. S. Afr. Mus., ix, pp. 578–580, fig. 37, *d–h.*

Sample 224 (forming a stratum on roots of *Typha*).

Lat. spor., 16 μ; long. spor., 21–26 μ.

Only single spores were observed, no chains.

This species was first recorded from Cape Colony.

(3) SCYTONEMATACEAE.

GENUS SCYTONEMA AGARDH.

1. *Scytonema bewsii*, Fritsch and Rich, n. sp. (Fig. 23).

S. inter alias algas aquaticas crescens, valde ramosa; pseudoramis fere semper geminatis, raro singulis, plerumque divergentibus et elongatis, in parte basali saepe angustioribus; vaginis crassis, luteo-fuscis (primo hyalinis in ramis juvenalibus), lamellatis, lamellis parallelis aut raro paullum divergentibus; trichomatibus cellulis cylindricis elongatis contentu granuloso aeruginoso, ad genicula haud constrictis; in parte apicali ramorum trichomatibus saepe e vaginis prominentibus et dilatatis cellulis discoideis; heterocystis elongato-cylindricis griseis vel coeruleis.

Lat. fil., 13–19 μ; lat. trich., 3·5–6 μ; lat. heterocyst., 5–7 μ; long. heterocyst., 16–19 μ.

Sample 229 (intermingled with *Zygnema pectinatum*).

This species bears a striking superficial resemblance to *S. mirabile* (Dillw.), Bornet, but it differs in the lesser dimensions of both filaments and trichomes, in the fact that the layers of the sheath are only very occasionally divergent, and that there is no thinning of the sheath towards

the apex ; other points of distinction are the frequent narrowing of the pseudo-branches at the point of origin (Fig. 23, *C*), and the elongate-cylindrical shape of the heterocysts (Fig. 23, *B*, *E*, and *F*). The habitat is moreover not that of *S. mirabile*. In many ways the new species combines the characteristics of *S. subtile* and *S. mirabile*, having the elongate cells and heterocysts and the narrowed bases of the branch-threads of the former and the coloured sheaths of the latter.

A comparison may also be instituted with *S. amplum*, W. & G. S. West
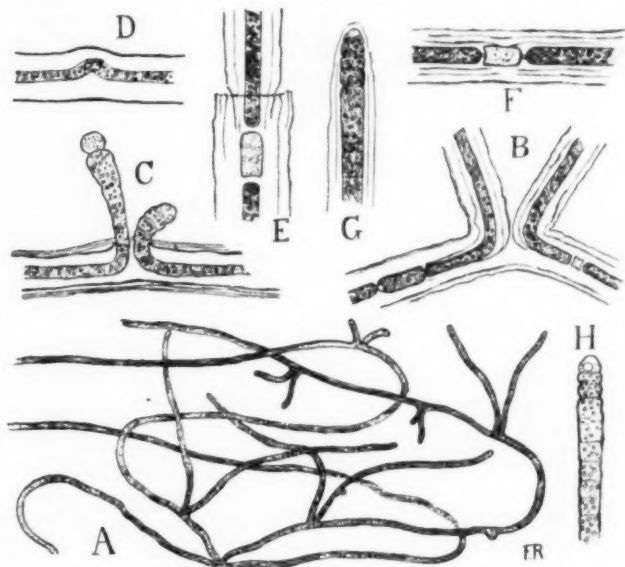
Fig. 23.—*Scytonema bewsii*, Fritsch and Rich, n. sp. *A*, small part of stratum teased out. Branching is shown in *B* and *C*, the typical form of the heterocysts in *B*, *E*, and *F*. *A* × 70 ; all other figures × 400

(Journ. Linn. Soc., Bot., xxx, 1894, p. 270, Pl. XVI, figs. 14–16), which differs however in its scanty branching, in the branches being thinner than the main axes, and in the distribution of colouration in the sheath. Further, this species was found in a terrestrial habitat. As regards this point, we cannot feel sure that the specimens of *S. bewsii*, found in sample 229, had not been washed down from a larger (and possibly terrestrial) stratum. In view of their very abundant ramification (*cf.* Fig. 23, *A*) and decidedly healthy appearance, however, this is not very likely and the species probably resembles *S. subtile*, Moeb. in occurring intermingled with other fresh-water forms.

2. *Scytonema mirabile* (Dillw.), Bornet ; Bornet et Flahault, *op. cit.*,
p. 101 ; Lemmermann, *op. cit.*, p. 212.

Sample 246 (rare).

Diam. fil., 17–21 μ ; diam. trich., 6–8 μ. Some of the sheaths were
colourless in their outer parts, as in var. *leprieurii* (Mont.), Bornet, but
by no means all showed this feature. This species has previously been
recorded from Cape Colony.

3. *Scytonema myochrous* (Dillw.), Ag. ; Bornet et Flahault, *op. cit.*,
p. 104 ; Lemmermann, *op. cit.*, p. 213. (Syn. : *S. tomentosum*, Kuetz.).

Sample 302 (intermingled in small quantity with *Calothrix parietina*
var. *africana*).

Diam. fil., 18–26 μ ; diam. trich., 8–9 μ.

Forma cellulis deplanatis, vaginis saepe ocreatis. Lat. fil., 39 μ ; lat.
trich., 11 μ.

Sample 309 (fragments).

Forma filis in caespitibus erectis, heterocystis subquadratis vel deplanatis,
lamellis vaginarum valde divergentibus. Diam. fil. ram. prim., 24–32 μ ;
diam. trich., 11 μ ; diam. fil. ram. ult., 21–28 μ ; diam. trich., 10 μ.

Sample 308.

This was an almost pure mass of *Scytonema* in which the majority of
the filaments with their branches formed dense upright tufts, probably
constituting a pilose velvety growth on the substratum. This is not a
method of growth usually mentioned in the diagnosis of this species,
although Messrs. West have recorded it for var. *chorographicum* (Journ.
Bot., 1897, p. 265). This variety is, however, distinguished by the sheaths
never being ocreate, which was frequently the case in the form under dis-
cussion. The material showed some points of resemblance to *S. mirabile*,
but the usually strongly diverging lamellae of the sheaths, and the occasion-
ally slighter width of the branches as compared with the main axes, has
led us to regard it as a form of *S. myochrous*.

4. *Scytonema splendens*, Fritsch and Rich, n. sp. (Fig. 24).

Filis valde ramosis, caespites erectos 5–6 mm. altos fusco-nigros for-
mantibus. Ramificatio filorum apices versus saepe plus copiosa, pseudo-
ramis aut singulis (vulgo juxta heterocystos quam in *Tolypothrix*) aut binis
aut ternis, iis geminatis saepe in eadem directione crescentibus. Rami
plerumque angulum parvum cum filis principalibus formant, vulgo eadem
latitudine, apices versus saepe brevissimi ; pseudoramis non raro intra
vaginam filorum principalium primo crescentibus. Vaginis obscure fuscis
vel luteo-fuscis, evidenter lamellatis et transverse striatis, partibus exteriori-
bus lamellis valde divergentibus praeditis, sed partibus interioribus non
lamellatis vel cum lamellis subparallelis paucis, trichomatibus saepe vagina
propria ; vaginis plerumque in apicibus filorum et ramorum paullo

attenuatis. Trichomatibus angustissimis pro latitudine vaginarum, inter
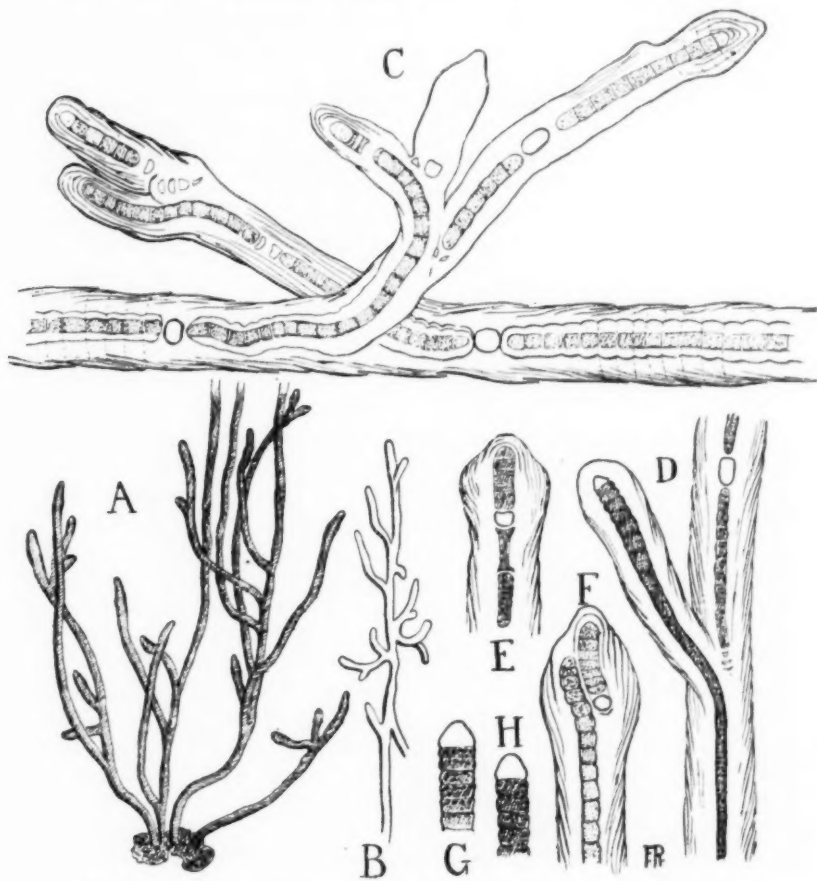cellulas valde constrictis, apicibus vulgo cellula apicali subconica vel

Fig. 24.—*Scytonema splendens*, Fritsch and Rich, n. sp. *A* and *B*, general
habit. *C–F* show character of sheath and trichomes. *G* and *H* are tips of
trichomes to show the special apical cells. *A* and *B* × 30; *G* and *H* × 800;
all other figs. × 400.

rotundata plus minus hyalina, contentu non granuloso; cellulis quadratis
vel latitudine longioribus vel brevioribus, aerugineis, contentu granuloso;
heterocystis fere semper singulis, formae diversae, sed vulgo deplanatis
vel quadratis.

Diam. fil., 32–37 μ ; diam. trich., 5–8 μ ; diam. heterocyst., 8–13 μ. Samples 298, 299.

This species appears to be very markedly characterised by its upright tufted growth (Fig. 24, *A*), its usual prolific branching with many short branches, the great width of the sheath as compared with that of the contained trichomes, and the complex structure of the sheath itself. The latter (Fig. 24, *C–F*) usually shows very distinct and strongly diverging layers in its outer portion, but the edge of the sheath is smooth (though somewhat uneven) and very rarely, as far as we have observed, even faintly ocreate. The inner part of the sheath, which is not sharply delimited against the contained trichome, however, not uncommonly shows no stratification at all (Fig. 24, *D–F*). In other cases one or two subparallel strata are distinguishable around the trichome, usually somewhat constricted opposite the septa and stopping short at the heterocysts, which are not encompassed by them (Fig. 24, *C*). In most filaments a rather faint transverse striation of the sheaths is apparent, the striae seemingly always corresponding to the constrictions between the cells (Fig. 24, *C*).

The false branching in many of the filaments is very abundant, but the majority of the branches are quite short and appear to be largely concerned in hormogone-formation (Fig. 24, *A–C*). The terminal part or even the whole branch often appears empty. The sheaths of these short branches are usually dilated slightly a little way from the apex, and beyond that run to more or less of a blunt point (Fig. 24, *D–F*). The short branches are nearly always in pairs, not uncommonly in threes and sometimes even in fours, the last two cases apparently being due to immediate false branching on the part of one or both branches of a pair. The longer branches, on the other hand, not uncommonly arise singly, and in that case are frequently formed beneath a heterocyst, as in *Tolypothrix*. The majority of the short branches are directed upwards, forming an acute angle with their main axes (Fig. 24, *A*, *B*, *D*), although the scanty specimens in sample 299 had more outstanding branches. There was usually no appreciable difference between the width of the different branches ; the width of the filaments is not, however, even throughout, since there are occasional local bulges, often at rather wide intervals. In many of the branches the apical cells appeared especially differentiated, being rounded or subconical in shape and devoid of the granular contents seen in the other cells (Fig. 24, *G* and *H*) ; as far as can be judged from preserved material, these cells must have been subhyaline in the fresh condition.

The species just described seems to be clearly characterised. We know of no species of *Scytonema* possessing this habit and exhibiting an equally prolific branching, a sheath of such complex structure, or such

relatively narrow trichomes. The only species with which a comparison might be undertaken is *S. myochrous* (Dillw.), Ag.

Genus TOLYPOTHRIX Kuetzing.

1. *Tolypothrix arenophila*, W. & G. S. West, Journ. Bot., 1897, p. 267. Sample 286.

Diam. fil., 14–18 μ ; diam. trich., 6–8 μ ; diam. heterocyst., 10 μ ; long., 18–19 μ.

The specimens, growing as a surface-film on sandstone rock, agreed well with Messrs. West's diagnosis, except that attenuation of the threads towards the apex could only rarely be observed. Characteristic of the species are the scanty short adpressed pseudo-branches, the thick strati-fied yellowish-brown sheaths, the elongated cells, and the usually solitary elongate-oblong heterocysts. At the points of branching, however, the heterocysts were commonly rounded or flattened. The young filaments within the stratum had quite colourless and relatively thin sheaths.

Attention may be drawn to the fact that in Lemmermann, Krypto-gamenflora der Mark Brandenburg, Algen, i, 1910, p. 221, the diagnosis of this species is interchanged with that of *T. crassa*, W. & G. S. West.

Genus PLECTONEMA Thuret.

1. *Plectonema tomasinianum* (Kuetz.), Bornet ; Gomont, *op. cit.*, p. 99 ; Lemmermann, *op. cit.*, p. 205.

Forma trichomatibus ramorum pro parte apices versus exigue attenuatis ; trichomatibus non semper inter cellulas distincte constrictis ; vaginis maturis valide materia ferruginea impregnatis. Diam. fil., 29–32 μ ; diam. trich., 18–21 μ ; diam. trich. ad apic., saepe 16 μ tantummodo.

Sample 235.

This form differed from the type in a few respects, especially in a frequent slight narrowing of the width of the trichomes in tracing them from the base to the apex of the branches, though this was not always marked. The sheaths were in most cases colourless, only a few showing the yellowish-brown colouration typical of the species. The outer part of the sheath appeared to be highly mucilaginous, and in this outer region abundant deposition of ferruginous matter had taken place in older filaments, often completely obscuring the contained trichome. Branching was not abundant, the false branches arising more frequently in pairs than singly. Constriction between the cells was not always clearly marked.

(4) STIGONEMATACEAE.

Genus STIGONEMA Agardh.

1. *Stigonema hormoides* (Kuetz.), Bornet et Flahault, *loc. cit.*, p. 68 : Lemmermann, *op. cit.*, p. 231.

Var. *africana*, F. E. Fritsch, nov. var. (Syn. : *S. hormoides*, Born. et Flah. *forma*, in Bews, Journ. Ecol., iv, 1916, p. 132.) (Fig. 25.)
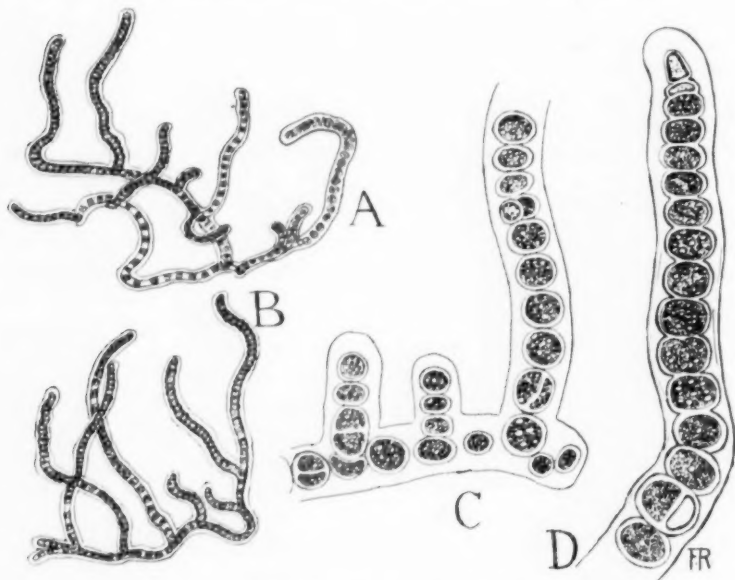

Fig. 25.—*Stigonema hormoides*, Bornet et Flahault, var. *africana*, Fritsch, n. var. *A* and *B* show the general habit ; *C* and *D*, parts of two filaments on a larger scale.   *A* and *B* × 200 ; *C* and *D* × 700.

Filis 11–14 μ latis, copiose ramosis et dense intricatis, stratum tomentosum inter alias species Stigonematis efficientibus ; ramis aut brevibus, aut elongatis et flexuosis, saepe praecipue unilateralibus, eadem latitudine quam filis principalibus.   Vaginis crassis, obscure lamellatis, in superficies interdum leviter longitudinaliter striatis, pro aetate flavis, luteo-fuscis, vel fuscis.   Trichomatibus vulgo vagina propria inter cellulas evidenter constricta ; cellulis 9 μ latis, plerumque globosis vel subglobosis, sed saepe evidenter deplanatis, nonnunquam ellipticis, fere semper uniseriatis, passim biseriatis, quae cum ita sint una cellula saepe heterocysta est ; heterocystis

etiam intercalaribus, quadratis vel deplanatis ; contentu cellularum valde granuloso.

Sample 294 (Bews' Nos. 104 and 105).

In Professor Bews' account of the vegetation of Natal (*loc. cit.*) this is referred to as a form of *S. hormoides.* Further investigation has, however, led to its recognition as a well-defined variety. It is distinguished from the type by its abundant branching (Fig. 25, *A* and *B*), by the deep brown colouration of the older sheaths which, even when young, are yellow and not colourless, by the differentiation of special sheaths around the cells (Fig. 25, *C* and *D*), and by the varying shape of the latter. The cells are almost invariably arranged in a single row, but here and there two cells are collateral (Fig. 25, *C* and *D*)--one of them often a heterocyst. It is very rare, however, for several pairs of such collateral cells to follow one another.

With regard to the rôle of this form in colonisation, see the introduction, p. 300. The type has been recorded from Cape Colony.

2. *Stigonema informe*, Kuetz. ; Bornet et Flahault, *op. cit.*, p. 75 ; Lemmermann, *op. cit.*, p. 233.

Sample 294 (Bews' Nos. 104 and 105).

Diam. fil., 36–51 μ.

This was quite typical material, except that few of the branches exceeded 40 μ in diameter. The cells were mostly quite densely arranged in several rows (6 or 8), and the sheaths were yellow or yellow-brown. Although there was an abundance of the material, little of it wore a healthy aspect, and it is probable that it was suffering from the competition with and the overshadowing by the associated *S. hormoides* var. *africana* which appeared very healthy. The thick, coarse threads evidently formed a creeping stratum, overlying an earlier growth of Chroococcales (*Gloeocapsa sanguinea* being still clearly recognisable), and giving rise to numerous branched, more or less upright tufts, many of them entwined by *Schizothrix epiphytica* or overgrown by *Stigonema hormoides* var. *africana.*

3. *Stigonema ocellatum* (Dillw.), Thuret ; Bornet et Flahault, *op. cit.* p. 69 ; Lemmermann, *op. cit.*, p. 231.

Var. *braunii* (Kuetz.), Hieronymus ; Lemmermann, *op. cit.*, pp. 228 232, fig. 10.

Sample 294 (Bews' Nos. 104 and 105).

Diam. fil., 17–32 μ. Many of the threads contained but a single row of usually flattened cells, and corresponded closely to the figure given by Lemmermann ; others, however, had two rows of cells almost throughout. The threads were usually well branched, the branches being narrower than the main axis. The thick sheaths were yellow or yellow-brown, the stratification not always being very obvious. This was apparently the

least abundant of the *Stigonemas* occurring in this habitat, and, like the last, in many cases presented a rather unhealthy appearance.

(5) RIVULARIACEAE.

Genus HOMOEOTHRIX Kirchner.

1. *Homoeothrix aequalis*, Fritsch and Rich, n. sp. (Fig. 26).
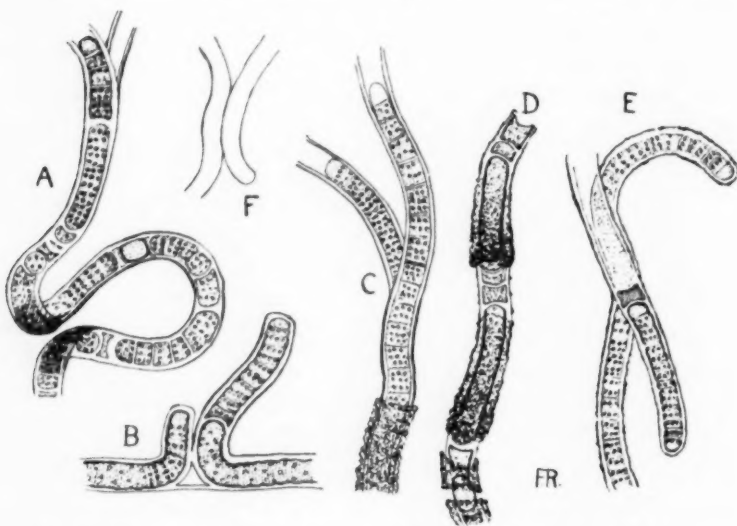Stratum inter muscos pallide aerugineum tomentosum ; filis dense

Fig. 26.—*Homoeothrix aequalis*, Fritsch and Rich, n. sp. *A*, *B*, and *F* show possible branchings ; *C*, *D*, and *E* show the incrustation of carbonate of lime. Biconcave cells are seen in many of the threads. All figs. × 450.

intricatis, valde flexuosis et fragilibus, brevibus vel elongatis, probabiliter copiose ramosis ; vaginis tenuibus hyalinis, non lamellatis, saepe calce in superficie induratis ; trichomatibus laete aerugineis inter cellulas constrictis, in pilum non productis, vix vel haud attenuatis, cellula apicali rotundata ; cellulis tam longis quam latis vel brevioribus, contentu granuloso parco ; cellulis biconcavis copiosis in filis pluribus.

Diam. fil., 9–11 μ ; diam. trich., 6–8 μ.

Sample 231.

We have been much puzzled by this form, which affords few decisive characters by means of which its generic position can be determined. In

view, however, of the neat rounding off of the sheath at one end of many
of the filaments (Fig. 26, *E–F*), and the fact that a slight inflation was
sometimes observable at these points (Fig. 26, *E* and *F*), we have come to
the conclusion that it must be referred to Rivulariaceae. Since there are
no heterocysts at the bases of the threads, it must be placed in the genus
Homoeothrix. Colourless cells resembling heterocysts were observed
occasionally in the course of the filaments, and once or twice at probable
points of branching; these cells, however, never showed any signs of
the polar thickenings typical of heterocysts, and we consider it very
doubtful whether they are anything more than dying cells of the trichomes.
The latter in most cases contained a considerable number of biconcave
and otherwise shaped moribund cells (Fig. 26, *A* and *E*), and it seems
probable that these occasionally simulate heterocysts. Few cases of
branching were actually observed (Fig. 26, *A–C*), but this appears to be
due to the early breaking away of the branch from the main thread.
Numerous short filaments were always to be found in which one end of the
sheath was irregularly ruptured, as though broken off from a previous
connection.

Accepting the form as a *Homoeothrix*, it is at once distinguished from
all the species hitherto described by the incrustation of the sheaths with
carbonate of lime and the almost complete absence of any attenuation in
the trichomes. In the latter feature it constitutes a striking parallel with
Calothrix brevissima, G. S. West.

The material showed abundant formation of hormogones.

Genus CALOTHRIX Agardh.

1. *Calothrix braunii*, Bornet et Flahault, *op. cit.*, p. 368; Lemmermann,
op. cit., p. 242 and p. 228, fig. 6.

Forma vaginis gelatinosis amplioribus, interdum lutescentibus.

Sample 306 (dense tufts growing on tangle of *Schizothrix fuscescens*, f.,
and also intermingled with upright filaments of the latter).

We think that the material in this sample is best referred to the above
species in spite of its aberrant sheath. The bases of the threads were
usually inflated, the trichomes tapered into a long hair, and the heterocysts
were mainly basal. *Cf.* also *C. castellii*, Bornet et Flahault.

2. *Calothrix gelatinosa*, Fritsch and Rich, n. sp. (Fig. 27).

Stratum inter muscos fuscum explanatum valde gelatinosum; filis
elongatis, raro ramosis, plerumque flexuosis et inter se intricatis; filis
trichomatibusque a basi apicem versus gradatim attenuatis; trichomati-
bus non in pilum productis, parte basali saepe dilatata, inter cellulas non
constrictis. Vaginis primo hyalinis gelatinosis margine exteriore distincte

definita, demum lutescentibus vel plus minus brunneis et saepe cum parte
exteriore hyalina vel dilute colorata et parte interiore obscure colorata,
basim versus non dilatatis parietibus illic attenuatis, plerumque indistincte
lamellatis praeter in filis maturis aliquibus; vaginis vetustis interdum
annulis transversis arcte congestis praeditis. Cellulis tam longis quam
latis vel paullum elongatis; heterocystis rotundatis vel elongatis, iis
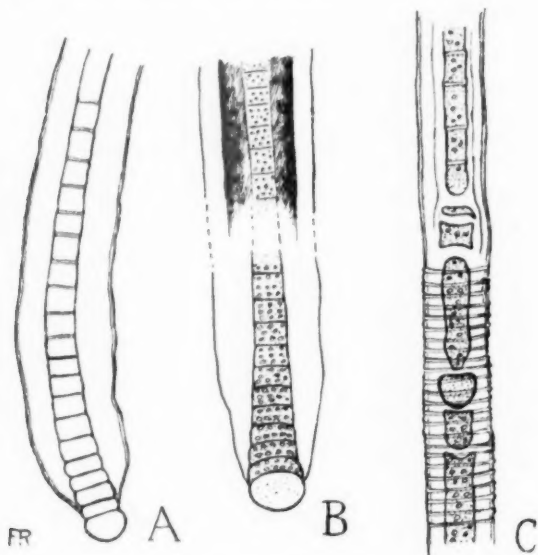basalibus plerumque non in vaginis inclusis.

Fig. 27.—*Calothrix gelatinosa*, Fritsch and Rich, n. sp. *A,* basal part of a
young filament, and *B,* of an older filament, the latter showing the two
zones of the sheath. *C,* part of an older filament with a sheath, showing
transverse annulation. All figs. × 600.

Diam. fil. ad bas., 22–26 μ, in media parte, 19 μ; diam. trich. ad bas.,
16 μ, in media parte, 6·5–8 μ; diam. heterocyst., 13 μ.

Sample 283.

The vast majority of the filaments in the stratum of this species showed
thick gelatinous sheaths, closely enveloping the contained trichomes and
showing no structure at all; many of these were quite colourless, others
yellowish or brownish. In what were probably the oldest filaments of the
stratum the sheaths were often firmer and distinctly differentiated into
two regions, the inner more or less deeply brown, the outer colourless or
less markedly coloured (Fig. 27, *B*). In some of these older filaments the

sheaths at occasional points showed densely placed transverse rings (Fig. 27, *C*), which may possibly be the result of the action of the preservative. Whilst the base of the trichome was in most cases very evidently inflated, the filaments as a whole did not show this feature, the sheaths gradually thinning out towards the base to accommodate the enlarged trichomes (Fig. 27, *B*). The basal heterocyst was usually not included in the
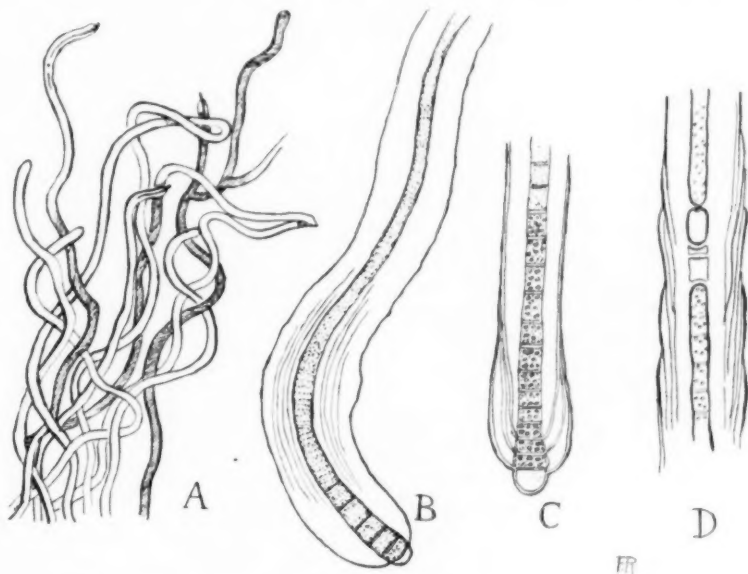

FIG. 28.—*Calothrix parietina* (Naeg.), Thuret, var. *africana*, F. E. Fritsch. *A*, small part of the stratum × 70 ; *B* and *C*, basal parts of two threads showing the usual characters of the sheath, etc. ; *D*, part of a filament showing divergent strata in the sheath. *B–D* × 600.

sheath. The above features, together with the very scanty branching, are probably sufficient to characterise this species.

3. *Calothrix parietina* (Naeg.), Thuret ; Bornet et Flahault, *loc. cit.*, p. 366 ; Lemmermann, *op. cit.*, p. 244.

Var. *africana*, F. E. Fritsch, nov. var. (Fig. 28).

Stratum fere nigrum, ca. 2 mm. crassum, in rupibus humidis explanatum ; filis elongatis valde flexuosis dense intricatis raro ramosis, a basi apices versus gradatissime attenuatis ; vaginis crassis, luteo-fuscis passim hyalinis, distincte lamellatis, lamellis parallelis vel passim divergentibus, interdum leviter ocreatis ; trichomatibus interdum paullo basim versus

inflatis, gradatissime acuminatis, non in pilum productis, inter cellulas plerumque non constrictis ; cellulis plerumque tam longis quam latis, basim versus saepe brevioribus, apicem versus saepe longioribus ; heterocystis basalibus membrana tenui hyalinis, singulis vel raro pluribus, heterocystis intercalaribus raris, quadratis vel valde elongatis.

Diam. fil. ad bas., 19–19·5 μ ; diam. trich. ad bas., 6·5–9 μ ; diam. fil. infra apic., 11–11·5 μ ; diam. trich. infra apic., 6·5 μ.

Samples 294, 302 (in the latter forming an almost pure stratum).*

It is possible that this should really be regarded as a separate species, although the general habit much recalls that of *C. parietina*. The variety is especially characterised by the highly flexuous elongate threads (Fig. 28, *A*) which, though attenuated, do not taper into a hair or to a point, and by the far less divergent character of the strata of the sheath (Fig. 28 *B–D*) which does not show the markedly ocreate appearance so distinctive of the type. Basal heterocysts are wanting on many of the threads and, when present, are colourless and very transparent. In most cases they are not included in the sheath (Fig. 28, *B*, *C*), and it seems that they very readily become detached. Branching is rare, many of the elongate threads showing no traces of it.

The sheath varies considerably. In some threads it is locally colourless, but more often deep brown. The strata frequently run parallel for long stretches, but sooner or later become divergent (Fig. 28, *D*). In some of the threads the sheaths show occasional slight bulges.

The *Calothrix africana* described by Schmidle (Engler's Bot. Jahrb., xxx, 1902, p. 249, Pl. V, fig. 11) seems to be nothing more than a form of *C. parietina*, from which it differs only in its prostrate habit and the possession of brownish-red sheaths ; *cf.* especially with the figure of *C. parietina* given in West's British Freshwater Algae, 1904, p. 339.

(Indeterminable material of *Calothrix* was also met with in samples 227, 246, 253, and 283.)

Genus 'RIVULARIA (Roth), Agardh.

1. *Rivularia* (*Gloeotrichia*) *natans* (Hedw.), Welwitsch ; Bornet et Flahault, *loc. cit.*, p. 369 ; Lemmermann, *op. cit.*, p. 253.

Sample 291.

The material was scarcely adequate for a quite satisfactory determination. The sheaths were hyaline, even those round the spores which were possibly not yet quite ripe. This species has already been recorded from Cape Colony.

* The rôle of this form in the colonisation of rock-surfaces is dealt with in Journ. of Ecology, iv, 1916, p. 132.

IV. FLORIDEAE.

(1) HELMINTHOCLADIACEAE.

Genus BATRACHOSPERMUM Roth.

1. *Batrachospermum huillense*, Welwitsch MS.; W. & G. S. West, Journ. Bot., 1897, p. 3. (Fig. nostr. 29.)

Samples 240, 241.

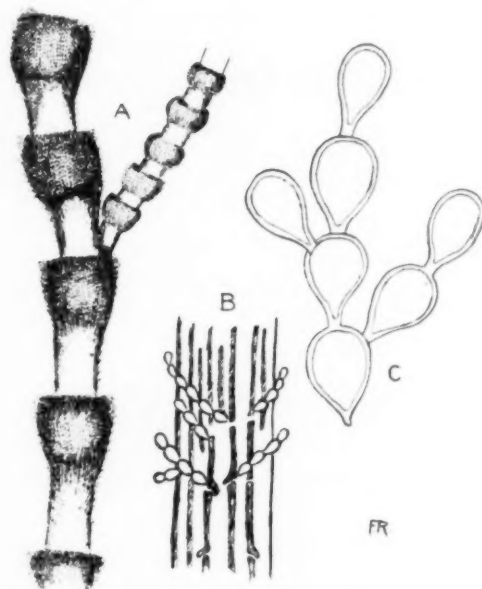This is the third record of this species from Africa, the two previous

Fig. 29.—*Batrachospermum huillense*, Welwitsch MS. *A*, general habit; *B*, part of main axis, showing cortical threads and secondary branches; *C*, part of one of the smaller branches. *A* × 50; *B* × 100; *C* × 1000.

ones being from Huilla in Angola and from Madagascar (*cf.* Fritsch, in Ann. d. Biol. lacustre, vii, 1914, p. 53). It is a very richly branched form, a character easily recognised already with a lens. A further distinctive feature lies in the wedge-like shape of the segments constituted by an internode and the superjacent node (Fig. 29, *A*), which is due to the dense crowding of the nodal and uppermost interstitial branches. The latter decrease in numbers as one passes down the internodes. Just above a

26

node the cortical threads covering the cells of the main axis are plainly
visible (Fig. 29, *B*). The individual cells composing the branchlets were
9–10 μ wide and about 14 μ long (*cf.* Fig. 29, *C*).

Genus CHANTRANSIA Fries.

1. *Chantransia chalybea*, Fries ; Kuetzing, Spec. Alg., 1849, p. 429 ;
Tab. Phycol., v, Tab. XLI.
Sample 293.
Previously recorded from Kentani.
(Another species of this genus was present in sample 310, but there
was too little for determination.)

V. BACILLARIEAE (DIATOMALES).

(*a*) CENTRICAE.

(1) MELOSIRACEAE.

Genus MELOSIRA Agardh.

1. *Melosira roeseana*, Rabenh. ; Smith, Brit. Diat., ii, 1853, p. 62,
Pl. LXI, fig. 386 ; Meister, Kieselalgen d. Schweiz, 1912, p. 40, Tab. I,
figs. 4, 5.
Samples 236 (rather rare), 273 (very common), 309 (rare).
Diam., 36–52 μ.

(2) COSCINODISCACEAE.

Genus CYCLOTELLA Kuetzing.

1. *Cyclotella meneghiniana*, Kuetz. ; Meister, *op. cit.*, p. 48, Tab. III,
fig. 5.
Sample 272 (very rare).
Diam., 18–24 μ.
Previously known from,the Karoo and Little Namaqualand.

(*b*) PENNATAE.

A. FRAGILARIOIDEAE.

(1) TABELLARIACEAE.

Genus DENTICULA Kützing.

1. *Denticula elegans*, Kützing, Bacill., p. 44, Tab. XVII, fig. 5 ; Meister,
op. cit., p. 59, Tab. V, fig. 3.
Sample 249 (rare ; long., 22 μ ; lat.. 6 μ).

2. *Denticula tenuis*, Kütz. ;   Smith, *op. cit.*, ii, p. 20, Pl. XXXIV, fig. 293 ;   Meister, *op. cit.*, p. 59, Tab. V, fig. 4.

Samples 238, 258, and 272 (in all cases rare).

Long., 38–42 *µ*.

Previously recorded from various parts of South Africa.

(4) FRAGILARIACEAE.

Genus SYNEDRA Ehrenberg.

1. *Synedra amphirhynchus*, Ehrenb. ;   Meister, *op. cit.*, p. 75, Tab. VIII, fig. 6.

Var. *fragilariaeformis*, Fritsch and Rich, nov. var. (Fig. 30, *A–C*).

Frustulis in taeniis longis modo *Fragilariae* conjunctis, saepe e cellulis 20–30 constantibus ; valvis in aspectu valvulari quam in typo, platea axiali interdum parum indistincta.   Long., 94–171 *µ* ;   lat., 7, 5–8 *µ* ;   striae ca. 7 in 10 *µ*.

Samples 239 (rather rare), 242, and 243.

We have referred these specimens to *Synedra* owing to the similarity of the valve-view to that of *S. amphirhynchus*.   The habit, however, shows a much closer resemblance to that of *Fragilaria*, and one might almost equally well call the form *Fragilaria synedraeformis*.   Specimens such as these show that there is no sharp boundary-line between the two genera.

2. *Synedra delicatissima*, W. Smith, *op. cit.*, i, p. 72, Tab. XII, fig. 94 ; Meister, *op. cit.*, p. 78, Tab. IX, fig. 3.

Samples 239, 242 (not uncommon).

Long., 240–290 *µ* ;   lat., 4–4. 5 *µ*.   Striae difficult to decipher.   Previously recorded from Little Namaqualand.

3. *Synedra longissima*, W. Smith, *op. cit.*, i, p. 72 ;   Meister, *op. cit.*, p. 74.

Var. *vulgaris*, Meister, *op. cit.*, p. 75, Tab. VIII, fig. 1.

Samples 238, 253 (rather common), 261, 265, 267, 269, 272 (common), 275, 276, 297, 303, 304, 309 (rare).

Long., 175–500 *µ* ;   lat. med., 6–9 *µ*.

Var. *acicularis*, Meister, *op. cit.*, p. 75, Tab. VIII, fig. 2.

Samples 272, 273, 297, 300, and 304.

Long., 350 *µ* ;   lat., 4, 5 *µ*.

4. *Synedra ulna* (Nitzsch), Ehrenb. ;   Meister, *op. cit.*, p. 71.

Var. *aequalis* (Kuetz.), Brun ;   Meister, *op. cit.*, p. 71, Tab. VII, fig. 1. (Syn. :   *S. aequalis*, Kuetz., Bacill., p. 66, Tab. XIV, fig. 14.)

Samples 219, 262, and 279 (rather common), 277 (common), 300, 303,

307 (in last three rare), and 470 (common, with occasional slight transitions
to var. *oxyrhynchus*, Van Heurck).

Long., 120–132 μ ; lat. med., 8–10 μ.   Widely distributed in South
Africa.

5. *Synedra vitrea*, Kuetzing, Bacill., p. 66, Tab. XIV, fig. 17 ; Meister,
op. cit., p. 77, Tab. VIII, fig. 5.

Samples 233, 235 (rather common), 236 (rare), 238, 249 (common),
251 (common), 261, 262, 275, 279, and 280 (in four last rather common).

Long., 176–288 μ ; lat. med., 7–8 μ.

This certainly approaches closely to *S. ulna*, some specimens merely
appearing as continuously striated types of the var. *aequalis* of this species.
Van Heurck is thus possibly right in regarding *S. vitrea* as a variety of
S. ulna.

Previously recorded from the Composite Region.

GENUS ASTERIONELLA HASSALL.

1. *Asterionella gracillima*, Heib. ; Rabenhorst, Fl. Europ. Alg., i,
p. 141 ; Meister, *op. cit.*, p. 79, Tab. IX, figs. 4–6.

Sample 258 (very rare).

Only a single colony was seen, but the species in question is likely to
be an important Plankton-constituent of the stream.

(5) EUNOTIACEAE.

GENUS EUNOTIA EHRENBERG.

1. *Eunotia (Himantidium) arcus*, Ehrenb. ; Smith, *op. cit.*, ii, p. 31 :
Meister, *op. cit.*, p. 89.

Var. *bidens*, Grun. ; Meister, *op. cit.*, p. 90, Tab. XI, fig. 15.

Sample 246 (rather rare)/

Long., 36–51 μ ; lat., 7–8 μ.

2. *Eunotia lunaris*, Grun. ; Meister, *op. cit.*, p. 83, Tab. IX, fig. 16.

Samples 246 and 470 (in both rare).

Previously recorded from Cape Colony.

3. *Eunotia (Himantidium) pectinalis*, Kütz. ; Meister, *op. cit.*, p. 87,
Tab. XI, fig. 3.

Var. *minor*, Grun. ; Meister, p. 87.

Samples 238 (not uncommon) and 275 (rare).

Long., 29–48 μ ; lat., 3–5 μ ; 9–10 striae in 10 μ.   The type is known
from various parts of South Africa.

4. *Eunotia (Himantidium) uncinata*, Ehrenb.; Smith, *op. cit.*, ii, p. 14, Pl. XXXIII, fig. 285; Meister, *op. cit.*, p. 90, Tab. XI, fig. 6.

Sample 246 (rare).

Long., 110–137 μ; lat., 4, 5–6 μ. Rather slender forms.

B. ACHNANTHOIDEAE.

(1) ACHNANTHACEAE.

Genus ACHNANTHES Bory.

1. *Achnanthes (Microneis) exigua*, Grun.; Cleve, Synops. Naviculoid Diat., ii, K. Sv. Vet.-Ak. Handl., xxvii, No. 3, 1895, p. 190; Meister, *op. cit.*, p. 98, Tab. XIII, figs. 7–9.

Sample 280 (rare).

Long., 16 μ; lat., 7 μ.

2. *Achnanthes (Achnanthidium) inflatum*, Kuetzing; Cleve, *op. cit.*, ii, p. 192; Meister, *op. cit.*, p. 100, Tab. XIII, figs. 19, 20.

Samples 236 (rare), 273 (common), 275 (rather rare).

Long., 42–55 μ; lat., 17–20 μ; 7 or 8 striae in 10 μ.

3. *Achnanthes (Microneis) microcephala*, Cleve, *op. cit.*, ii, p. 188; Meister, *op. cit.*, p. 97, Tab. XII, figs. 21, 22.

Sample 231 (not uncommon).

(2) COCCONEIDACEAE.

Genus COCCONEIS Ehrenberg.

1. *Cocconeis placentula*, Ehrenb.; Cleve, *op. cit.*, ii, p. 169; Meister, *op. cit.*, p. 93, Tab. XII, figs. 4, 5.

Sample 290 (rare).

Previously recorded from Cape Colony and Angola.

C. NAVICULOIDEAE.

(1) NAVICULACEAE.

Genus NAVICULA Bory.

Section *Diploneis* Ehrenberg.

1. *Navicula (Diploneis) elliptica*, Kuetz.; Cleve, *op. cit.*, i, p. 92; Meister, *op. cit.*, p. 104, Tab. XIV, fig. 6.

Samples 258, 265, 280, 303, 305, and 307 (in all cases rare).

Long., 22–50 μ; lat., 11–26 μ.

Recorded by G. S. West from Angola.

Section *Neidium* Pfitzer.

1. *Navicula* (*Neidium*) *amphirhynchus*, Ehrenb. ; Meister, *op. cit.*, p. 107, Tab. XIV, fig. 16.

Samples 272 (rare) and 282 (rare).

Long., 61–64 μ ; lat., 17–18 μ.

2. *Navicula* (*Neidium*) *bisulcata*, Lagerstedt, Bih. K. Sv. Vet.-Ak. Handl., i, No. 14, 1873, Tab. I, fig. 8.

Var. *turgidulum* (Lagerst.), Meister, *op. cit.*, p. 108, Tab. XV, fig. 1.

Sample 297 (rare).

Long., 51–53 μ ; lat., 11 μ.

Section *Anomoeoneis* Pfitzer.

1. *Navicula* (*Anomoeoneis*) *zellensis*, Grunow, Verhandl. Zool. Bot. Ges. Wien, 1860, p. 521, Tab. III, fig. 34 ; Cleve, *op. cit.*, ii, p. 7 ; Meister, *op. cit.*, p. 118, Tab. XVII, fig. 10 (Fig. nostr. 30, *H*).

Samples 272 and 282 (rare).

Long., 45–53 μ ; lat. med., 9, 5–12 μ.

We have little doubt that the Diatom whose valve-view is shown in Fig. 30, *H*, belongs to Grunow's species, although larger and more especially broader than any specimens hitherto recorded. The individuals are distinctly triundulate, with slightly protruded poles. The median area is narrow and the central area small and more or less rounded. The striae are densely arranged and very strikingly parallel with one another ; under oil immersion lenses they resolve themselves into transverse series of punctae, the striae opposite the central area consisting of only a few of these. This species seems to stand very close to *N. hitchcockii*, Ehrenb., as figured by Donkin (Nat. Hist. Brit. Diat., p. 29, Pl. V, fig. 4).

Section *Naviculae orthostichae* Cleve.

1. *Navicula ambigua*, Ehrenb. ; Cleve, *op. cit.*, ii, p. 110 ; Meister, *op. cit.*, p. 135, Tab. XX, fig. 13. (Syn. : *N. cuspidata*, Kuetz. var. *ambigua*, Ehrenb.)

Samples 249, 261, 267, and 269 (rare in all except 267).

Long., 75–77 μ ; lat., 19 μ.

Previously recorded from the Cape Province.

Section *Frustulia* Agardh.

1. *Navicula* (*Frustulia*) *vulgaris*, Thw. ; Cleve, *op. cit.*, i, p. 122 ; Meister, *op. cit.*, p. 121, Tab. XVIII, fig. 4. (Syn. : *Vanheurckia vulgaris*, Van Heurck.)

Samples 239, 242, 258, 279, 280, and 289 (common only in 280).

Long., 45–74 μ ; lat., 10–13 μ.

Recorded from the Cape Province by Fritsch.

Section *Naviculae mesoleiae* Cleve.

1. *Navicula bacilliformis*, Grun. ; Cleve, *op. cit.*, i, p. 131 ; Meister, *op. cit.*, p. 130, Tab. XIX, fig. 23 ; v. Schoenfeldt, Bacillariales, Suesswasserfl. **x**, 1913, p. 80, fig. 150.

Forma striis medianis nullis ita ut area centralis stauroneiformis est. Long., 28–37 μ ; lat., 10 μ.

Samples 249 and 269 (rare).

The specimens agreed best with the figure and description given by Schoenfeldt (*loc. cit.*), there being an obvious slight constriction beneath the poles causing the ends to appear slightly swollen. The median area was broadened out into a stauros reaching the margin of the valve on either side. *Cf.* with *Stauroneis heufleriana*, Grun., as figured by Schumann, Diat. d. hohen Tatra, Vienna, 1867, Tab. IV, fig. 62.

2. *Navicula kotschyi*, Grun. ; Cleve, *op. cit.*, i, p. 130 ; Meister, *op. cit.*, p. 129, Tab. XIX, fig. 18.

Sample 222 (not uncommon).

Long., 19–20 μ ; lat., 4·5 μ.

Section *Naviculae lineolatae* Cleve.

1. *Navicula anglica*, Ralfs ; Cleve, *op. cit.*, ii, p. 22 ; Meister, *op. cit.*, p. 146. (Syn. : *N. tumida*, W. Smith.)

Var. *minuta*, Cleve, *op. cit.*, p. 22 ; Meister, *op. cit.*, p. 146, Tab. XXII, fig. 13.

Samples 468 and 470 (rare).

Long., 26 μ ; lat., 8 μ.

The type previously recorded from Cape Colony.

2. *Navicula cincta*, Grun. ; Cleve, *op. cit.*, ii, p. 16 ; Meister, *op. cit.*, p. 138, Tab. XXI, fig. 6.

Samples 219, 235, and 290 (rather frequent in 235).

Long., 30–34 μ ; lat., 6 μ.

Previously known from Cape Colony and Orange Free State.

3. *Navicula cryptocephala*, Kuetz. ; Cleve, *op. cit.*, ii, p. 14 ; Meister, *op. cit.*, p. 138, Tab. XXI, fig. 3.

Sample 290 (common).

Long., 28 μ ; lat., 6 μ. This species stands very close to *N. rhynchocephala*. It is widely distributed in South Africa.

4. *Navicula radiosa*, Kuetz. ; Cleve, *op. cit.*, p. 17 ; Meister, *op. cit.*, p. 139, Tab. XXI, fig. 13. (Syn. : *N. acuta*, W. Smith.)

Samples 262, 267, 272, 280, and 300 (rather common in two last).

Long., 61–80 μ ; lat., 10–11 μ.

Already recorded from Cape Colony.

5. *Navicula rhynchocephala*, Kuetz. ; Cleve, *op. cit.*, p. 15 ; Meister, *op. cit.*, p. 139, Tab. XXI, fig. 9.

Samples 219, 235, 249, 261, 262, 267, 279, 282, and 290 (common in 262, 267, and 290).

Long., 43–53 μ ; lat., 9–11 μ.

Already known from various parts of South Africa.

6. *Navicula tenella*, Bréb. ; Cleve, *op. cit.*, p. 17 ; Meister, *op. cit.*, p. 140, Tab. XXI, fig. 14.

Samples 219, 235, 249, 305, 307 (rare in three last).

Section *Pinnularia* Ehrenberg.

1. *Navicula (Pinnularia) acrosphaeria*, Rabenh. ; Cleve, *op. cit.*, ii, p. 86 ; Meister, *op. cit.*, p. 155, Tab. XXVI, fig. 4.

Samples 262 and 272 (rare).

Long., 88–107 μ ; lat., 11 μ.

Var. *minor*, Cleve, *op. cit.*, p. 86 ; Meister, *op. cit.*, p. 155, Tab. XXVI, fig. 5.

Samples 249 and 258 (rare).

Long., 50–77 μ ; lat., 11 μ.   This species is very easily recognised by its short parallel striae and dotted median area.

2. *Navicula (Pinnularia) borealis*, Kuetz. ; Cleve, *op. cit.*, ii, p. 80 ; Meister, *op. cit.*, p. 158, Tab. XXVII, fig. 3.

Samples 261, 265, 273, 280, 289, and 303 (common only in 273).

Long., 27–53 μ ; lat., 7·5–12 μ.   Forma *rectangularis*, Carlson, also present.

Already recorded from Cape Colony.

3. *Navicula (Pinnularia) divergens*, W. Smith, *op. cit.*, i, p. 57, Pl. XVIII, fig. 177 ; Meister, *op. cit.*, p. 160.

Var. *elliptica*, Grun. ; Cleve, *op. cit.*, ii, p. 79 ; Meister, *op. cit.*, p. 160, Tab. XXVII, fig. 8.

Sample 253 (rare).

Long., 106 μ ; lat., 33 μ ; 7 ribs in 10 μ.

4. *Navicula (Pinnularia) interrupta*, W. Smith, *op. cit.*, i, p. 59, Pl. XIX, fig. 184 ; Cleve, *op. cit.*, p. 76 ; Fritsch, Ann. S. Afr. Mus., ix, p. 590 *et seq.*

Samples 238 (f. *biceps*, Cleve, very rare), 272 (forma (*c*) below), 275 (f. *braunii*, rare), 282 (not uncommon), and 468 (not uncommon, f. *pseudomesolepta*, *cf.* below).

All the forms present in samples 282 and 468 showed interruption of

the striae at the middle of the valve and appear to be capable of classification under three series :—

(*a*) Forms closely resembling f. *braunii*, Fritsch (*loc. cit.*, p. 592, especially fig. 40, *a*), but differing somewhat among one another in the degree of curvature of the sides in valve-view. Long., 67–75 μ ; lat., 10–11, 5 μ.

(*b*) Forms closely resembling f. *genuina*, Fritsch (*loc. cit.*), but differing in having very slightly retuse sides ; long., 53–54 μ ; lat., 10 μ. They thus approach f. *bicapitata* (*P. bicapitata*, Lagerstedt), except for the interruption of the striae at the middle of the valve. The apices are, however, far more pronouncedly capitate than in f. *bicapitata* (*loc. cit.*). This therefore adds one more to the diversity of forms enumerated by Fritsch, *loc. cit.*, p. 592. A close approximation to this form is figured by Meister on Tab. XXVIII, fig. 9, as *P. interrupta* var. *stauroneiformis*, Cleve, although our specimens showed a more pronounced retuseness. These forms certainly differ somewhat from that depicted on Pl. XIX, fig. 184, in Smith's British Diatomaceae, which is what Cleve called f. *stauroneiformis* and which should in our opinion be regarded as the type-form of the species.

(*c*) Forma *pseudomesolepta*. This third form was observed in sample 468 and intermingled with the others in sample 282. Long., 43–54 μ ; lat., 8–11 μ. It approximates closely to *P. microstauron*, Cl. var. *ambigua*, Meister (*op. cit.*, p. 162, Tab. XXVIII, fig. 2), but might equally well be regarded as an ill-developed form of *P. mesolepta*, W. Sm. var. *stauroneiformis*, Cl. (Meister, *op. cit.*, p. 162, Tab. XXVIII, fig. 5). We have little doubt that such forms altogether bridge the gap between *P. interrupta* and *P. mesolepta* (*cf.* Fritsch, *loc. cit.*, p. 592).

The specimens of f. *braunii*, Fritsch (*loc. cit.*), present in sample 275 were frequently provided with a very slight median inflation appearing as an exaggerated convexity at this point. It is clear that the forms of this species are widely distributed in South Africa.

5. *Navicula* (*Pinnularia*) *madagascariensis*, Fritsch, Ann. d. Biol. lacustre, vii, 1914, p. 55, Pl. I, fig 9.

Sample 282 (rare).

Long., 115–156 μ ; lat., 20–23 μ.

As already previously mentioned (Ann. S. Afr. Mus., ix, p. 594) this is possibly a form of *N. distinguenda*, Cleve (*P. viridis*, Smith, *op. cit.*, Pl. XVIII, fig. 163, *a*).

6. *Navicula* (*Pinnularia*) *major*, W. Smith, *op. cit.*, i, p. 54, Pl. XVIII, fig. 162 ; Meister, *op. cit.*, p. 153, Tab. XXV, fig. 1 (sub. var. *lacustris*, Meister).

Samples 246, 272, 275, 300 (rare in all).

Long., 150–186 μ ; lat., 20–32 μ.

Previously recorded from Cape Colony.

7. *Navicula* (*Pinnularia*) *mesolepta*, W. Smith, *op. cit.*, i, p. 58 ; Meister, *op. cit.*, p. 162.

Sample 303 (very rare).

Long., 54 μ ; lat., 10 μ.   Not very strongly undulate.

Previously recorded from Cape Colony.

Var. *africana*, Fritsch and Rich, nov. var. (Fig. 30, *I*).

N. parva ; valvis in aspectu valvulari linearibus, leviter undulatis undulationibus aequalibus ita ut margines valvarum subparallelis videuntur ; polis productis et leviter capitatis, ca. dimidia latitudine quam media parte valvae, saepe subrhomboideis apicibus acuminatis ; striis in media parte valvae interruptis.   Long., 52–60 μ ; lat. med., 9–10 μ ; lat. apic., 5–6 μ.

Samples 239, 242, 246, 261, 300, 303 (rare in all cases).

This is a well-marked form which should perhaps be regarded as a new species.   The undulation is not nearly as pronounced as in the published forms of this species, and the three undulations are moreover of the same width (Fig. 30, *I*).   Another striking feature is constituted by the apices which are produced and only slightly capitate, being about half as wide as the rest of the valve ; they are usually of a characteristic sub-rhomboidal shape with pointed extremity.   *Cf.* the figure of f. *stauronei-formis* given by Mueller (Forschungsber. Biol. Stat. Ploen, vi, 1898, Tab. III, fig. 21).

8. *Navicula* (*Pinnularia*) *stauroptera*, Rabenh. ; Cleve, *op. cit.*, ii, p. 82 ; Meister, *op. cit.*, p. 159.

Var. *interrupta*, Cleve, p. 83.

Sample 258 (rare).

Long., 98 μ ; lat., 14 μ.

Previously recorded from Cape Colony.

9. *Navicula* (*Pinnularia*) *viridis*, Ehrenb. ; Meister, *op. cit.*, p. 150.

Var. *elliptica*, Meister, *op. cit.*, p. 150, Tab. XXIII, fig. 4.

Samples 246, 265, and 297 (rare), 272, 280, 468 (in the last three not uncommon).

Long., 99–130 μ ; lat., 16–22 μ ; 7–9 ribs in 10 μ.

This seems to be a well-defined form which is, however, probably the same as *P. distinguenda*, Cleve (= *P. viridis*, Smith, *op. cit.*, Tab. XVIII, fig. 163, *a*).   Whether it should be regarded as a separate species is doubtful.   *P. madagascariensis*, Fritsch, is connected with this form by transitions.

GENUS STAURONEIS EHRENBERG.

1. *Stauroneis acuta*, W. Smith, *op. cit.*, i, p. 59, Pl. XIX, fig. 187 ; Meister, *op. cit.*, p. 125, Tab. XIX, fig. 6.   (Syn. : *Pleurostauron acutum*, Rabenh.)

Sample 289 (rare).

Long., 80 μ ; lat., 13 μ.

2. *Stauroneis anceps*, Ehrenb. ; Cleve, *op. cit.*, i, p. 147 ; Meister, *op. cit.*, p. 123.

Var. *birostris* (Ehrenb.), Cleve, *op. cit.*, p. 147 ; Meister, *op. cit.*, p. 124, Tab. XVIII, fig. 11.

Samples 235 and 310 (in both rare).

Long., 61–84 μ ; lat., 16–18 μ.

Var. *lata*, Fritsch and Rich, nov. var. (Fig. 30, *J*).

Differt a omnibus formis hactenus descriptis valvis latis lanceolatis ; striis radiantibus confertis e punctis compositis, contra aream centralem striis brevibus unilateraliter vel utrinque ; polis productis haud capitatis. Long., 65–80 μ ; lat., 24–27 μ.

Sample 236 (rather rare).

This is a much broader form than any hitherto described for this species. The type has been recorded from the Composite Region and Holle River.

3. *Stauroneis phoenicentron*, Ehrenb. ; Smith, *op. cit.*, p. 59, Pl. XIX, fig. 185 ; Cleve, *op. cit.*, p. 148.

Samples 246 and 272 (rare).

Long., 78–114 μ ; lat., 16–22 μ.

Previously recorded from the Cape Province by Fritsch.

Genus GYROSIGMA Hassall.

1. *Gyrosigma acuminatum*, Kuetz. ; Cleve, *op. cit.*, p. 114 ; Meister, *op. cit.*, p. 119.

Samples 258, 267, 269, 272, 282, 290 (rare, except in 267 and 290).

Long., 84–126 μ : lat., 13–18 μ.

Previously recorded from the Orange Free State by Fritsch.

(2) GOMPHONEMACEAE.

Genus GOMPHONEMA Agardh.

1. *Gomphonema brachyneura*, Mueller, Engler Bot. Jahrb., xxxvi, 1905, p. 145, Tab. I, fig. 7 (Fig. nostr. 30, *D*, *E*).

Samples 235, 258, 262, 280. 297, 307, 470 (rare in 235 and 258).

Long., 22–42 μ ; lat., 4–8 μ.

This is one of the *Gomphonemas* provided with short ribs and possessed of a wide lanceolate median area. Moreover, it belongs to those which are provided with a stigma (Fig. 30, *D*), *i.e.* a separate puncta on one side of the central area. These include the species *G. brachyneura*, Muell., *G. entolejum*, Oestrup (Bot. Tidsskrift, xxv, 1903, p. 30, Tab. I, fig. 4),

G. frickei, Mueller (*loc. cit.*, p. 145, Tab. I, fig. 6), and *G. sparsistriatum*, Muell. (p. 145, fig. 8), all of which differ essentially from one another only in
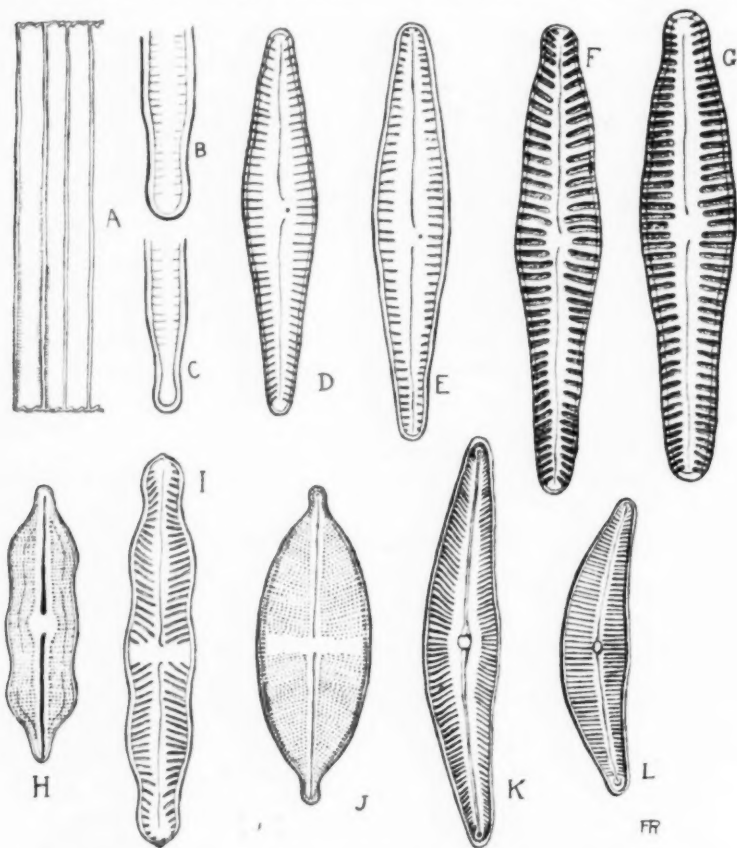

Fig. 30.—*A–C*, *Synedra amphirhynchus*, Ehrenb. var. *fragilariaeformis*, Fritsch and Rich, n. var. (*A* × 350, *B* × 1000, *C* × 850). *D, E, Gomphonema brachyneura*, Muell. (×1600). *F, G, G. crassestriatum*, Fritsch and Rich, n. sp. (×1400). *H, Navicula zellensis*, Grun. (× 900). *I, N. mesolepta*, Sm. var. *africana*, Fritsch and Rich, n. var. (× 1000). *J, Stauroneis anceps*, Ehrenb. var. *lata*, Fritsch and Rich, n. var. (× 700). *K, Cymbella helvetica*, Kuetz. var. *africana*, Fritsch and Rich, n. var. (× 700). *L, C. maculata*, Kuetz. forma (× 550).

dimensions and the number of striae per 10 μ, the number being 13–15, 11–12, 10, and 6–7 for the four species respectively. It seems scarcely justifiable to maintain four species on such a slender basis, and it would

probably be better to regard all four as different forms of one and the same species.   Our specimens showed 11–12 striae in 10 μ.

2. *Gomphonema constrictum*, Ehrenb. ;   Cleve, *op. cit.*, p. 186 ;   Meister, *op. cit.*, p. 167, Tab. **XXVIII**, fig. 15.

Sample 235 (very rare).

Long., 39 μ ;   lat., 11 μ.

Previously recorded from the Orange Free State by Fritsch.

3. *Gomphonema crassestriatum*, Fritsch and Rich, n. sp. (Fig. 30, *F*, *G*).

Valvis lanceolatis, polo basali quam apicali angustiore, latitudine maxima in media parte valvae, basim versus primum subito deinde sensim attenuatis, apicem versus gradatissime attenuatis, supra mediam interdum levissime dilatatis, infra apicem plus minus constrictis.   Striis elongatis, robustis, ubique radiantibus, area mediana in parte superiore valvae angusta, area centrali parva indistincta, stigma nulla.   Long., 45–51 μ ; lat., 8–10 μ ;   striis ca. 8–9 in 10 μ.

Samples 261, 262, 280, 303, and 304 (common in 262 and 280).

This species is characterised by the shape of its valves and the coarse radiating striae.   The basal pole is narrower than the apical one, the greatest width of the valves being at about the middle.   Below this point there is a sudden tapering, followed by a more gradual one, whilst towards the apex of the valve there is a uniform narrowing till within a short distance of the tip, where a more or less well-marked constriction is observable. This species somewhat resembles *G. intricatum*, Kuetz., from which it is distinguished by the shape of the upper half of the valve, the radiating striae, and the absence of a stigma.   It may also be compared with *G. olivaceum*, Kuetz., which has differently shaped valves, a distinctive central area, and finer striae.

4. *Gomphonema parvulum*, Grun. ;   Cleve, *op. cit.*, p. 180 ;   Meister, *op. cit.*, p. 173, Tab. **XXIX**, fig. 11.

Samples 235, 261, 262, 275, 297, 468 (not uncommon in the two first).

Long., 19–35 μ ;   lat., 5–5, 5 μ.

Previously known from Little Namaqualand and Cape Colony.

(NOTE.—In sample 470 a form was observed resembling the marine *G. exiguum*, Kütz ;   there was, however, insufficient to make sure of the determination.)

(3) COCCONEMACEAE.

Genus CYMBELLA Agardh.

1. *Cymbella amphicephala*, Naeg. ;   Cleve, *op. cit.*, i, p. 164 ;   Meister, *op. cit.*, p. 185, Tab. **XXXI**, fig. 14.

Sample 297 (rather rare).

Long., 38–40 μ ; lat., 10–11 μ.

2. *Cymbella delicatula*, Kütz. : Cleve, *op. cit.*, p. 161 ; Meister, *op. cit.*, p. 184, Tab. XXXI, fig. 9.

Sample 295 (not uncommon).

This is one of the smallest species of the genus. Long., 15–21 μ.

3. *Cymbella helvetica*, Kuetz. ; Cleve, *op. cit.*, p. 174 ; Meister, *op. cit.*, p. 180.

Var. *africana*, Fritsch and Rich, nov. var. (Fig. 30, *K*).

C. mediocris, margine dorsali constanter sed non valde convexa, margine ventrali fere plana in media parte exigue convexa raro leviter concava. Raphide in media valva, fere recta ; area mediana minus angusta quam in typo, gradatim polos obtusos versus attenuata. Striis in margine ventrali brevioribus et densioribus quam in margine dorsali, valde radiantibus, praecipue in media valva. Long., 61–88 μ ; lat., 14–19 μ ; striis 7–8 in 10 μ.

Samples 282, 307 (in both rare), 309 (common), 310 (rather rare).

In the form of the valve the specimens of this variety usually agreed best with the figure in Smith's British Diatomaceae (Pl. II, fig. 24, *a*), but they differed in the pronounced radiation of the striae near the middle of the valves and the rather wider median area (*cf.* Fig. 30, *K*). The figures of *C. helvetica*, Kuetz., given by v. Schoenfeldt (Bacillariales, in Suesswasserfl. Deutschlands, etc., x, 1913, p. 137, fig. 300) and Meister (*op. cit.*, Tab. XXIX, fig. 22 ; Tab. XXX, figs. 4–6) differ more fundamentally from the new variety in the shape of the valves, since in the first-named's figure the ventral margin as a whole appears distinctly concave though with a faint median convexity, whilst in Meister's figures the dorsal margin is not uniformly convex. In all the specimens observed in the above-named samples the shape of the valves as regards the dorsal margin was very markedly constant, the only respect in which the individuals differed among one another being in the width of the median area and the straight or slightly concave outline of the ventral margin.

The type has already been recorded from Kentani.

4. *Cymbella maculata*, Kuetz. ; Meister, *op. cit.*, p. 182, Tab. XXXI, fig. 3. (Syn. : *C. cistula*, Hempr. var. *maculata*, Kütz.)

Sample 249 (rare).

Long., 77 μ ; lat., 14 μ.

Previously known from the Orange Free State.

Forma margine ventrali fere recta, in media parte tamen leviter convexa, striis per totam valvam subparallelis. Long., 58–72 μ ; lat., 16–18 μ ; striis ca. 6 in 10 μ (Fig. 30, *L*).

Samples 249, 307, 309, and 310 (not uncommon in 307).

C. *maculata*, Kuetz., is regarded by Cleve and others as a form of

C. cistula, Kirchn. The specimens here recorded (Fig. 30, *L*) all had the very narrow median area characteristic of the species, but differed in the almost straight ventral margin and the remarkable parallel character of the striae throughout the valve.

5. *Cymbella ventricosa*, Kuetz.; Cleve, *op. cit.*, p. 168; Meister, *op. cit.*, p. 190.

Var. *obtusa*, Cleve, *op. cit.*, p. 169; Meister, *op. cit.*, p. 191, Tab. XXXIII, fig. 2.

Samples 219, 235, 239, 249, 261, 267, 269, 272, 290, and 470 (common only in 239).

Long., 22–35 μ; lat., 7–9 μ.

The type has been recorded from Orange Free State.

Genus AMPHORA Ehrenberg.

1. *Amphora ovalis*, Kuetz.; Cleve, *op. cit.*, ii, p. 104; Meister, *op. cit.*, p. 193.

Var. *gracilis*, Van Heurck; Meister, *op. cit.*, p. 193, Tab. XXXIII, fig. 10. Sample 275 (rare).

The type is known from Cape Colony and Orange Free State.

Genus EPITHEMIA Brébisson.

1. *Epithemia argus*, Kuetz., Bacill., p. 34; Meister, *op. cit.*, p. 198. Samples 265, 305, 307, 309 (in all cases rare).

Long., 48–86 μ; lat., 12–14 μ. Probably a form of var. *longicornis*, Grun., but the specimens were not as broad as those recorded by Meister.

2. *Epithemia sorex*, Kuetz., Bacill., p. 33, Tab. V, fig. 12, *a–c*; Meister, *op. cit.*, p. 197, Tab. XXXIII, fig. 20.

Samples 295 (rare), 297 (common).

Previously recorded from the Orange Free State by Fritsch.

Forma margine ventrali saepe fere recta, apicibus haud valde capitatis. Long., 30–67 μ; lat., 11–16 μ; costis ca. 5 in 10 μ.

Samples 299, 305, 307, 309, 310 (common in 307 and 309).

In the shape of the valve this form bears a considerable resemblance to the figure in Smith's British Diatomaceae (Pl. I, fig. 9, *a*); the complete frustules, however, were more broadly ovate and did not show the slight protrusion of the apices illustrated in Smith's fig. 9, *b*. On the other hand, the figures given by Schoenfeldt (*op. cit.*, p. 145, fig. 319) and Meister (*op. cit.*, Tab. XXXIII, fig. 20) show a much more profound concavity of the ventral margin and a more obvious capitate character of the apices than was usually the case in our specimens. The range of size was very considerable, although falling practically within the limits given by Meister.

All the specimens seen possessed three of the characteristics of the species, viz. the delicate nature of the dots composing the striae between the ribs, the marked radiation of the latter, and the swinging out of the two portions of the raphe as concave lines practically to the middle of the dorsal surface.

The occurrence of this form in sample 309 as an epiphyte on *Spirogyra* is of interest.

3. *Epithemia turgida* (Ehrenb.), Kuetzing, Bacill., p. 34; Meister, *op. cit.*, p. 196.

Var. *genuina*, Grun.; Smith, *op. cit.*, Tab. I, fig. 2; Meister, *op. cit.*, p. 196, Tab. XXXIII, fig. 17.

Samples 292 (on *Spirogyra* sp.), 295, 299, 305, 307, 309, 310 (common in 299 and 309).

Long., 61–104 μ; lat., 13–16 μ; about 4 costae in 10 μ.

The specimens varied somewhat as regards the degree of concavity of the ventral margin which was in some cases almost straight; otherwise there was good agreement with the figure given by Meister. Occasional individuals were more sharply curved and approached var. *plicata*, Meister. The rows of dots between the costae were usually two or three in number, but attention must be drawn to the fact that in many specimens the costae occurred at rather irregular intervals, and in such cases as many as four rows of dots might be counted between the more widely spaced ribs. The figures in Smith, Schoenfeldt, and Meister show on the whole such regular spacing of the costae in the different species of *Epithemia* that it has seemed well to emphasise this irregularity.

4. *Epithemia zebra* (Ehrenb.), Kuetzing, Bacill., p. 34; Meister, *op. cit.*, p. 199.

Var. *porcellus*, Grun.; Meister, *op. cit.*, p. 200, Tab. XXXV, figs. 2–4.

Samples 236 and 297 (rather common), 305, 307, and 309 (rare).

Long., 66–114 μ; lat., 11–12, 5 μ.

The figures and description of the type given by Meister are not in agreement with those in Smith and Schoenfeldt, nor with those in Migula (Kryptogamenflora, ii, 1907, Pl. X, fig. 19). We have identified our specimens with the figures given by Meister and Migula (*loc. cit.*, Pl. X, *D*, fig. 3) of var. *porcellus*; the specimens in sample 236 were especially typical.

Genus RHOPALODIA O. Mueller.

1. *Rhopalodia gibba*, O. Muell.; Meister, *op. cit.*, p. 200, Tab. XXXV, fig. 6. (Syn.: *Epithemia gibba*, Kuetz.)

Samples 253 (not uncommon), 269, 305, and 309 (rare).

Long., 101–238 μ; lat. frustul., 22–28 μ.

In sample 253 this species and *R. parallela*, Muell., were connected by

numerous transitional forms, and it was difficult in many cases to draw the distinction between them. *R. gibba* has already been recorded from Little Namaqualand by G. S. West and from the Orange Free State by Fritsch.

2. *Rhopalodia gibberula* (Kuetz.), Muell. ; Schoenfeldt, *op. cit.*, p. 148, fig. 326. (Syn. : *Epithemia gibberula*, Kuetz.)

Samples 231 (not uncommon), 232 (rare).

Long., 24–69 μ.

Previously recorded from Cape Colony.

3. *Rhopalodia parallela*, Muell. ; Meister, *op. cit.*, p. 201. (Syn. : *Epithemia gibba*, Kuetz., var. *parallela*, Grun.)

Samples 253 (common), 297 (not uncommon), 300 (rather rare).

Long., 212–224 μ ; lat. frustul., 18–22 μ.

4. *Rhopalodia ventricosa*, Muell. ; Meister, *op. cit.*, p. 201, Tab. XXXV, fig. 8. (Syn. : *Epithemia ventricosa*, Kuetz.)

Samples 253 (common), 299, 300, 305, 307, and 309 (in the five last rare).

Long., 64–84 μ ; lat. frustul., 26–29 μ.

D. NITZSCHIOIDEAE.

(1) NITZSCHIACEAE.

Genus NITZSCHIA Hassall.

Section *Tryblionella* Grunow.

1. *Nitzschia* (*Tryblionella*) *hantzschiaeformis*, Fritsch and Rich, n. sp. (Fig. 31, *A–C*).

Valvis anguste lanceolatis, apices versus rapide angustatis, apicibus aliquantulum productis et interdum levissime capitatis, plerumque plus minusve concavis in uno latere et rectis vel convexis in altero latere ; striis distinctis in media valva interruptis, in parte centrali valvarum striis in uno latere deficientibus ; punctis carinae indistinctis.

Long., 43–51 μ ; lat., 8–9, 5 μ.

Sample 235 (rather common).

This form has a great superficial resemblance to a *Hantzschia*, but it differs altogether in the very feeble development of the carinal dots, in the interruption of the striae along the middle line of the valves, and in the smooth one-sided area in the central region (fig. 31, *A–C*). In the first two respects it betrays its affinity to the species of the section *Tryblionella*. The form of the valves is somewhat variable.

Var. *constricta*, Fritsch and Rich, nov. var. (Fig. 31, *D*).

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Valvis in uno latere profunde concavis, in altero latere distincte convexis ; alioqui typa similis est.

Long., 39–57 μ ; lat., 8 μ.

Sample 235 (rare).

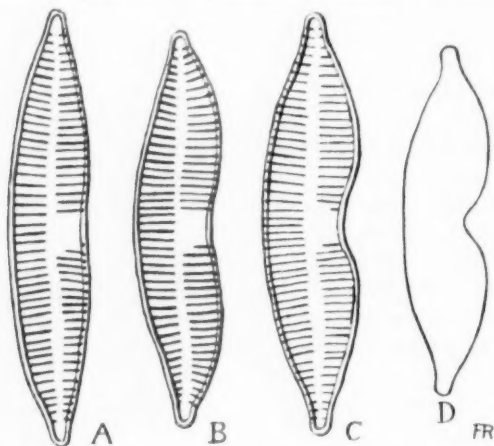2. *Nitzschia* (*Tryblionella*) *tryblionella*, Hantzsch ; Meister, *op. cit.*,

FIG. 31.—*A–C, Nitzschia hantzschiaeformis*, Fritsch and Rich, n. sp.   Valves of three individuals.   *D, N. hantzschiaeformis*, Fritsch and Rich, var. *constricta*, n. var.   All figures × 1300.

p. 147.   (Syn. : *Tryblionella tryblionella*, Hantzsch ; v. Schoenfeldt, *op. cit.*, p. 150, fig. 331).

Var. *victoriae*, Grunow ; v. Schoenfeldt, *op. cit.*, p. 151.

Samples 219, 235, 249, 253, 258, 261, and 275 (never common).

Long., 43–57 μ ; lat., 18–24 μ.

Section *Apiculatae* Grunow.

1. *Nitzschia hungarica*, Grun. ; Meister, *op. cit.*, p. 206, Tab. XXXVI, fig. 10.

Samples 219, 249, and 267 (rare in all cases).

Previously recorded from the Cape Province and Orange Free State by Fritsch.

Section *Dubiae* Grunow.

1. *Nitzschia stagnorum*, Rabenh. ; v. Schoenfeldt, *op. cit.*, p. 153, fig. 337.

Sample 272 (rare).

Long., 53 μ ; lat., 9 μ.

Previously recorded from the Calvinia Division and Orange Free State.

Section *Sigmoideae* Grunow.

1. *Nitzschia sigmoidea* (Ehrenb.), W. Smith, *op. cit.*, i, p. 38, Pl. XIII. fig. 104 ; Meister, *op. cit.*, p. 209, Tab. XXXVII, fig. 6.

Samples 219, 235, 249, 258, 261, 262, 267, 269, 272, 275, 277, 279, 290 (rare except in 249, 261, and 275).

Long., 141–192 μ.

Already recorded from Cape Colony and Orange Free State.

Section *Sigmatae* Grunow.

1. *Nitzschia clausii*, Hantzsch ; Meister, *op. cit.*, p. 210, Tab. XXXVIII, fig. 1.

Samples 258, 262, 282 (never common).

Long., 38–45 μ ; lat., 3, 5 μ.

2. *Nitzschia sigma*, W. Smith, *op. cit.*, p. 39, Pl. XIII, fig. 108 ; Meister, *op. cit.*, p. 210, Tab. XXXVII, fig. 10.

Samples 253, 267, 272, 275, and 282 (rare except in 272 and 282).

Previously known from Cape Colony.

Section *Lineares* Grunow.

1. *Nitzschia recta*, Hantzsch ; Meister, *op. cit.*, p. 211, Tab. XXXVIII, fig. 6.

Sample 249 (rare).

Long., 74 μ ; lat., 6 μ.

Section *Lanceolatae* Grunow.

1. *Nitzschia communis*, Rabenh. ; Meister, *op. cit.*, p. 214, Tab. XXXVIII, fig. 12.

Samples 222, 238, and 297 (rare in 238).

Long., 22–26 μ ; lat., 4, 5–5 μ.

Already recorded from Cape Colony and Orange Free State.

2. *Nitzschia inconspicua*, Grun.; Meister, *op. cit.*, p. 215 ; v. Schoenfeldt, *op. cit.*, p. 160, fig. 355.

Sample 219 (rare).

3. *Nitzschia palea*, Kuetz. ; Meister, *op. cit.*, p. 213, Tab. XXXVIII, fig. 9 ; v. Schoenfeldt, *op. cit.*, p. 159, fig. 352.

Samples 233, 235, 249, 261, 262, 267, 269, and 290 (rare except in 235, 267, and 290).

A species of wide distribution in South Africa.

Genus HANTZSCHIA Grunow.

1. *Hantzschia amphioxys* (Ehrenb.), Grun. ; Meister, *op. cit.*, p. 203, Tab. XXXVI, fig. 2.

Samples 235, 258, 261, 262, and 273 (in all cases rare).

Recorded from Little and Great Namaqualand by G. S. West and from the Cape Province and Orange Free State by Fritsch.

E. SURIRELLOIDEAE.

(1) SURIRELLACEAE.

Genus CYMATOPLEURA Turpin.

1. *Cymatopleura solea* (Bréb.), W. Smith, *op. cit.*, i, p. 36 ; Meister, *op. cit.*, p. 216 ; Mueller in Engler's Bot. Jahrb., xxxiv, 1903, p. 21.

Var. *clavata*, Mueller, *loc. cit.*, p. 22, fig. 4.

Sample 249 (rare).

Long., 101 μ ; lat. max., 27 μ ; lat. min., 22 μ.

This variety is chiefly characterised by the shape of its apices, the lateral margins of which are straight or even convex instead of being concave as in the type.

Var. *pygmaea*, Pant. ; Meister, *op. cit.*, p. 217, Tab. XXXVIII, fig. 18.

Samples 258 and 277 (rare).

Long., 52–56 μ ; lat., 11–17 μ.

Forms of this species have already been recorded from Angola and Orange Free State.

Genus SURIRELLA Turpin.

1. *Surirella angusta*, Kuetz. ; Smith, *op. cit.*, p. 34, Pl. XXXI, fig. 260 , Meister, *op. cit.*, p. 223, Tab. XLI, fig. 8.

Sample 262 (rare).

Long., 45–48 μ ; lat., 16 μ.

2. *Surirella apiculata*, W. Smith, *op. cit.*, ii, p. 88 ; Meister, *op. cit.*, p. 224, Tab. XLI, fig. 9.

Samples 239 (rare), 290 (rather common).

Long., 27–35 μ ; lat., 8–8, 5 μ. Ends not always very markedly produced.

3. *Surirella biseriata*, Bréb. ; Smith, *op. cit.*, i, p. 30, Pl. VIII, fig. 57 ; Meister, *op. cit.*, p. 224, Tab. XLII, fig. 1.

Samples 246 (rare), 280 (rather common).

Long., 59–154 μ ; lat., 21–39 μ ; ribs 1, 5–2 in 10 μ. In many of the specimens the ribs alternated on the two sides of the valves.

4. *Surirella linearis*, W. Smith, *op. cit.*, i, p. 31, Pl. VIII, fig. 58 ; Meister, *op. cit.*, p. 222, Tab. XLI, fig. 3.

Sample 258 (rare).

Long., 66 μ ; lat., 15 μ.

Only few of the specimens resembled Meister's figure in having parallel sides and equally tapering ends. Most more closely resembled fig. 58, *a*, of Smith, in which one end is broader than the other, tapering being more pronounced towards the narrower end of the valve. In extreme cases such specimens acquire a wedge-like shape somewhat resembling that of *S. splendida*, though much less wide.

This species has already been recorded from Cape Colony.

5. *Surirella ovalis*, Bréb. ; Meister, *op. cit.*, p. 229, Tab. XLVI, fig. 4.

Samples 249, 267, and 269 (rare in last two).

Long., 46–54 μ ; lat., 24–30 μ ; 4–5 ribs in 10 μ.

The specimens had more pointed apices than that drawn by Meister (*loc. cit.*), in this respect agreeing well with the figure in Migula (Krypto-gamenflora, Pl. XIV, fig. 2).

This species has been recorded from the Holle River and Little Namaqualand by G. S. West and from the Cape Province by Fritsch.

6. *Surirella splendida*, Kuetz. ; Meister, *op. cit.*, p. 227, Tab. XLIV, fig. 3.

Samples 258, 261, 272, 275, 282, 310 (common in 258, 272, and 282).

Long., 90–168 μ ;. lat., 32–50 μ ; about 1, 8 ribs in 10 μ.

Genus STENOPTEROBIA Brébisson.

1. *Stenopterobia anceps* (Lewis), Bréb. ; Mueller, Forschungsber. Biol. Stat. Ploen, vi, 1898, pp. 80, 81, Tab. III, figs. 35–37 ; v. Schoenfeldt, *op. cit.*, p. 172, fig. 376. (Syn. : *Surirella anceps*, Bréb.)

Samples 258 and 267 (rare).

A small form ; long., 80–92 μ ; lat., 6–10 μ. *Cf.* var. *heribaudi*, Play-fair, Proc. Linn. Soc. New S. Wales, xxxvii, 1912, Tab. LVI, figs. 21, 22 (= *S. anceps*, Heribaud).

VI. FLAGELLATAE.

(*d*) EUGLENINEAE.

Genus EUGLENA Ehrenberg.

(Although species of *Euglena* were present in several samples—218 (common), 261, 266 (common), 268 (common), 287 (common)—they were unfortunately too badly preserved for identification.)

Genus LEPOCINCLIS Perty.

1. *Lepocinclis ovum* (Ehrenb.), Lemmermann, in Suesswasserflora, ii,
1913, p. 134, fig. 216.
Samples 257 and 261 (in both rare).
Long., 37–58 μ ; lat., 26–40 μ.
Already recorded from Cape Colony.

Genus PHACUS Dujardin.

A species of this genus was encountered in sample 234, but could not
be determined.

Genus TRACHELOMONAS Ehrenberg.

1. *Trachelomonas hispida* (Perty), Stein ; Lemmermann, *op. cit.*, p. 149,
fig. 272.
Samples 255, 256, 257 (rare in 256).
Already recorded from Cape Colony.
2. *Trachelomonas oblonga*, Lemmermann, *op. cit.*, p. 147, fig. 278.
Forma major.   Long., 35 μ ; lat., 27 μ.
Sample 257 (very rare).
The specimen had a flagellum at least three times the length of the
body of the cell.   In the cell-contents a distinct basal body was recognis-
able (a pyrenoid ?).
This species is known from various parts of Cape Colony.
3. *Trachelomonas volvocina*, Ehrenb. ; Lemmermann, *op. cit.*, p. 145,
fig. 246.
Samples 257 and 261 (rare in both).
Already recorded from various parts of Cape Colony.